Electrical Engineering

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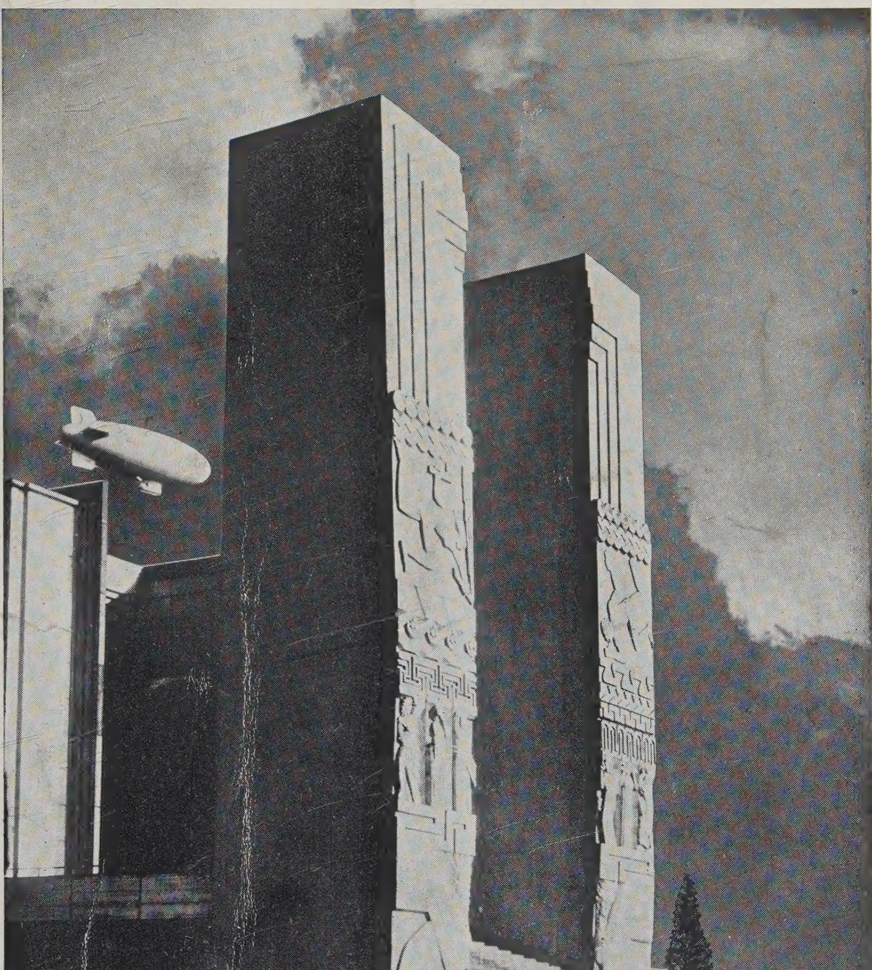

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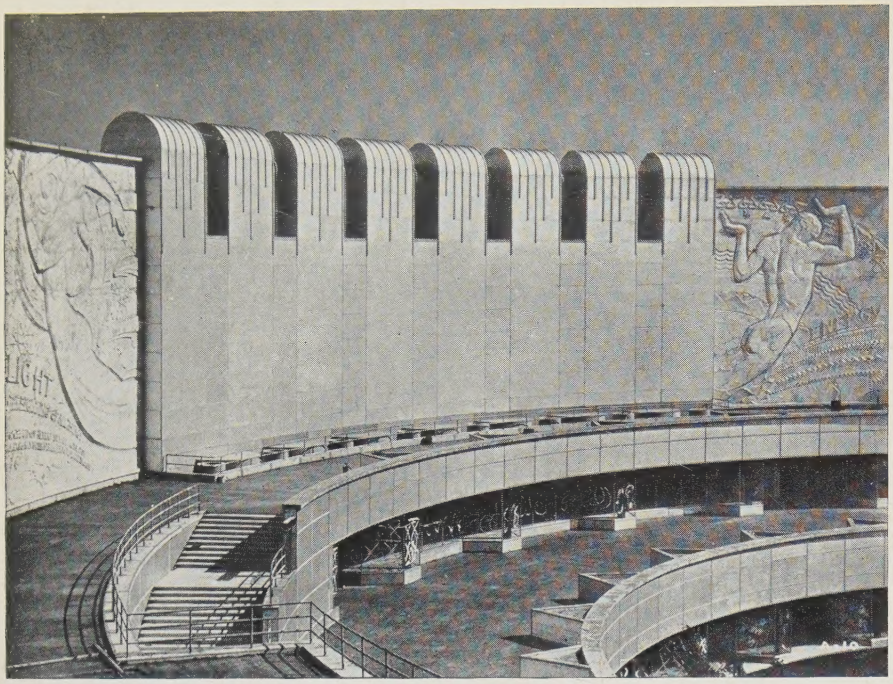
American Institute of Electrical Engineers



Modernistic and daring in its architectural design is the Electrical Building of Chicago's 1933 World's Fair—A Century of Progress Exposition. This vast semi-circular structure, embellished with striking sculptured placques, paved terraces, dramatic illumination and coloring will house exhibits showing the generation, distribution, and utilization of electricity.

At Chicago—June 26-30, 1933

Forty-Ninth Annual Summer Convention of the

American Institute of Electrical Engineers

The Conquest of Time and Space—striking modernistic bas-relief—rises over the west entrance to Communications Hall. The central 24-ft figure of this relief depicts the genius of electrical communication, rising from the dynamo, its outstretched arms encompassing the world of radio, telephone, and telegraph, its form bathed in the effulgence issuing from a floodlight. On the left is a symbolic figure of electrical science, on the right a figure of the Dark Ages.

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This Month—

Front Cover

Covered with symbolic bas-reliefs of the forces of electricity, these twin pylons guard the water gate to the electrical building of the electrical group of A Century of Progress—Chicago's 1933 World's Fair. In the electrical group will be dramatized the advance of electrical industries since the pioneer days of Pascal, Morse, Edison, and Marconi.

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Officers and Committees (For complete listing see p. 678–81, September 1932 issue of ELECTRICAL ENGINEERING)

SOME of the statements made in "A Theory of Neon Tube Operation" which appeared in Electrical Engineering for November 1932, have been elaborated by means of additional oscillographs, curves, and explanations. *p. 304–7*

THE United States is now linked by commercial radio communication with more than 40 other nations. The extremely rapid growth in this type of communication during the past several years has been made possible by the introduction of low cost high frequency vacuum tube transmitters. *p. 331–7*

VACUUM tube rectifiers for furnishing high voltage direct current to electrical precipitators have many advantages over the mechanical rectifiers now commonly being used. Experience with a few installations indicates a higher recovery per kilowatt input than is obtained with mechanical rectification. *p. 337–40*

OVERLOAD and heating tests on polyphase squirrel cage motors of moderate size show that ordinary overload relays rated at 115 per cent of full load motor current furnish satisfactory protection to such motors against damage when locked, overloaded, or single phased. *p. 327–31*

SIMPLE squirrel cage induction motors, formerly considered applicable only to constant speed service, now are beings built with a great variety of speed-torque characteristics. *p. 323-6*

BECAUSE the economic and physical conditions of the territories served by an electric utility, as well as conditions in the utility itself, are continually changing, it is important to analyze the different cost items periodically. One of the principal uses of such an analysis is in the economic selection of the method of generating power in combined steam and hydroelectric systems. *p. 313–8*

THE annual meeting of the A.I.E.E. will be held during the summer convention as usual. *p. 345*

LETTERS from readers of Electrical Engineering published in this issue include discussions on reactive power, economic conditions, and balancing submarine communication cables. *p. 350-2*

CORRECTION.—In the article "Operating Aspects of Reactive Power" by J. Allen Johnson appearing in Electrical Engineering for April 1933, p. 266, the cuts for parts(a) and (b) of Fig. 3 should have been interchanged.

REACTIVE POWER is a subject to which will be devoted an entire session at the North Eastern District meeting to be held in Schenectady, N. Y., May 10–12. One of the papers giving some theoretical considerations on the subject is published in full in this issue. *p. 319–23*

FINAL plans are now being made for the North Eastern District meeting of the A.I.E.E. to be held in Schenectady, N. Y., May 10–12. *p. 349.* Abstracts of all papers approved at the time of printing, except those previously published in Electrical Engineering, are included in this issue. *p. 341–2*

RADIO plays an extremely important part in maintaining regularly scheduled flight and safety in air transportation. With a satisfactory radio compass it is possible to navigate an aircraft with great accuracy, and when combined with a magnetic compass a system is obtained which automatically corrects for wind drift. *p. 307–13*

WITH the "Century of Progress" Exposition being staged in Chicago this summer, the 1933 A.I.E.E. summer convention to be held in that city June 26–30, affords an excellent opportunity to combine business with pleasure. Six technical sessions are scheduled in addition to several joint meetings with other engineering and technical societies which are holding meetings in Chicago during the same week. Plans are being made for the usual summer convention sports competition. *p. 343–7*

The Balancing of

Economic Forces*

Second Progress Report of American Engineering Council

TWO years ago the American Engineering Council assigned to its committee on the relation of consumption, production, and distribution this commission:

"The selection and recommendation of such governmental, financial, and business policies as will maintain in the United States a standard of living that is high, broadly distributed, and free from severe fluctuations."

On January 16, 1932, the committee submitted to Council its first progress report. (Essentially full text of the first report was contained in ELECTRICAL ENGINEERING for June 1932, p. 373–9.) That report outlined the method of attack which has been adopted, offered an hypothesis as to the occurrence of the existing business recession, and gave an outline of apparent causes which had contributed to that event. It also considered briefly a few of the remedies which had been proposed. The 2 most constructive results obtained from the distribution of the first progress report are: (1) A collection of over 200 reviews, in many cases including extensive discussions, offered by eminent men engaged in a wide range of business and professional activities; and (2) a file of more than 50 suggested remedial plans.

The second progress report of Council is divided into 2 parts: (1) An analysis of 40 alleged causes of business instability, and (2) a selected group of 23 individual plans to prevent or minimize the effects of business recession. Part 1 of this second progress report is presented herewith in essentially full text, without comment, but with an open invitation for comments, criticisms, and suggestions. —The Editors.

Second Progress Report

The second progress report is divided into 2 parts:

1. An analysis of 40 alleged causes of business instability, classified as primary, contributory, incidental, or doubtful.

2. An analysis of the theories, principles, and methods of a selected group of 23 plans offered to prevent or to minimize the effects of business recession. (Part 2, consisting of the 23 plans each offered by a different individual or individuals, is not included in this issue of ELECTRICAL ENGINEERING.)

An Analysis of 40 Causes of Business Instability

While the committee has taken into account numerous international factors which affect the domestic problem, it has not sought to lay the foundation for international solutions. There is good reason for this decision; while certain elements of the economic problem are world-wide, other ruling factors are pure national. The problem in the United States is simple in contrast with that in other nations. Here population is not pressing on subsistence. Our national prosperity need not be dependent upon the export of a substantial part of our total production. We need not divert our energies to the development of virgin resources, nor to the building up of manufacturing equipment. We are not divided into hostile political segments, but form one country, large in extent, varied and ample in natural resources and in the capacities and abilities of the people. The assignment definitely limited the investigation to the long-time problem; no consideration was to be given in the first instance to emergency measures.

Alleged Causes of Instability

Numerous causes for economic instability have been alleged. A knowledge and evaluation of them is essential to an understanding of the problem with which the committee is dealing. The committee has grouped into 7 general classes all alleged causes which have come to its attention. These classes are: Psychological, technological, business performance, savings and investment, financial, agricultural, and governmental. Each alleged cause has been analyzed for the purpose of determining whether it had a primary, contributory, incidental, or doubtful effect upon (*a*) business stability, (*b*) scale of living, and (*c*) inequality of distribution.

Psychological Causes

It has been contended that the instability of business is primarily due to successions of states of

* Essentially full text of part 1 of the second progress report of American Engineering Council's committee on the relation of consumption, production, and distribution: R. E. Flanders, *chairman*, L. P. Alford, F. J. Chesterman, Dexter S. Kimball, F. H. McDonald, L. W. Wallace, and W. J. Wilgus.

In signing this report Mr. Wilgus desires to express his belief that in it sufficient stress has not been given to betrayals of trust and other violations of common honesty as primary factors in the upsetting of economic stability. He considers that this is a real underlying cause not to be lightly dismissed as of secondary effect.

mind. This being true, it is probably a potent factor in effecting the various changes in the business cycle. Both at the peak of the boom and the bottom of the recession the psychological factors predominate in importance so far as the immediate situation is concerned.

One cause of the inhibiting emotions is the betrayal of trust. Far too many examples in both large and small business operations have become public during the current depression. Such revelations undermine public confidence, foster hoarding, breed suspicion, and unsettle business.

(a) Business Stability. The committee does not believe perfect stability, or a near approach to it, is possible of attainment. Nor is the committee even sure that such a state is a desirable objective, for there appear to be creative and rejuvenating forces in moderate, rhythmical variations in the volume of business. However, the present degree of variation is destructive, and must be brought under such a measure of control as will insure the safety of our social structure.

(b) Scale of Living. A rise in the scale of living is physically possible of attainment to a degree little comprehended by those unfamiliar with the available productive mechanisms, processes, and organization. Except in occasional and unimportant instances these were not operating to their capacity during the peak of the last boom. The scale of living made possible by existing facilities and which is within easy reach, is that resulting from maximum production and not the mean of the variations of production.

(c) Distribution of Goods. A wider and larger distribution of goods produced is in one respect a problem in social justice. However, it is here considered as an economic circumstance. The committee believes a better distribution, that is, more to classes now enjoying few or almost no goods, is physically attainable without any substantial diminution in the share now obtained by those rendering useful services. The larger share of the possible increases in production should go to those who are able and willing to work, but who are now poorly served by the social mechanism.

Technological Causes

Inefficiency in production resulting in costs so high as to make business unprofitable is charged with being a primary factor in business instability. Actually, efficiency has greatly increased in the manufacture of most staple products during the last decade, yet there has been a severe business depression. Despite these facts there exists a vague feeling that if efficiency can be still further increased and wastes still further reduced, business will be on a firmer basis. This belief is probably due to a confusion in considering the evident advantages for the individual firm in an increase in efficiency with its possible temporary disadvantages in its general effect.

Inefficiency in production must be classed as a contributory cause of business instability and a hindrance to the wider distribution of goods, and as a primary bar to rise in the scale of living.

Inefficiency in distribution is perhaps dependent upon efficiency in production. It is a doubtful cause of business instability and restriction of distribution, but is a contributory bar to a rise in the scale of living.

General overproduction is frequently assigned as a disturbing result of the use of highly efficient machinery. There can be overproduction in special lines, particularly those of inelastic demand, such as staple foodstuffs; but a survey of the scale of living of the majority of workers dispels the idea that there has been general overproduction. As a cause of business recession, general overproduction must therefore be classed as a highly doubtful influence.

Technological unemployment is claimed to accompany general overproduction. Apparently the assumption is that more is made, while purchasing power is not increased, or is even decreased. The answers to this point of view are 2:

1. Improved efficiency will result in a lowered price to the consumer, or an increased profit to the producer, or both. In the first instance consumption will be increased by the lowered price, and in the second the producer's profits will be expended in increased consumption, or the purchase of new capital goods. Doubts as to the beneficial effects of these processes are raised in later paragraphs under "Causes Relating to Savings and Investment."

2. New processes, new occupations, and the various services required by new inventions, reemploy those displaced. However, when the details of the process of finding new jobs are observed, as described in paragraphs immediately following, the reemployment situation is dubious.

Technological unemployment is a possible, though doubtful, unfavorable primary factor in its influence on stability, scale of living, and distribution. Its contributory effects are not subject to question.

Instability of Occupation. Manufacturers have observed with dismay that improved efficiency in production is not easily translated into lower prices or higher profits. The concurrent growth in selling expense has frequently canceled the improvement in manufacturing cost. There is a growing suspicion that the 2 tendencies are not separate but are connected, perhaps in the following way:

When men are displaced either by machines or by more efficient selling, they tend to obtain reemployment in selling in one of 2 typical ways: they engage in house-to-house selling, or open service establishments—unneeded gas stations, for instance; or they may be employed by a manufacturer who is expanding his sales department under the pressure of necessity for output. The reengaged worker is employed under more hazardous conditions than are those who remain in production activities—particularly those producing the staples of subsistence. Here is a probable element of unbalance, but also an undesirable, although effective, way of maintaining a connection with the economic machine for large numbers who might otherwise be cast off.

There are other sources of occupational instability. As a result of improvements in production, a continuously smaller percentage of workers is concerned with the making of the more stable staples, while a growing percentage is dependent on the fluctuating demand for articles of taste and luxury. Except for its unbalancing effect this process is desirable. Another variety of occupational instability is that concerned with the manufacture of capital goods—machinery, manufacturing and business buildings, engineering structures, etc. These industries, for obvious reasons, get the full impact due to the variations of the business cycle. It has been shown that the entire drop in consumption for the years 1930 and 1931 might be accounted for by the decrease in capital goods produced and in consumer goods used by those dependent on capital-goods production.

Psychological factors in this analysis are classed as contributory, adversely affecting business stability. At the same time it is recognized that in certain stages of the business cycle certain of such factors may be properly classed as primary in their effect. One cause of the inhibiting emotions can be properly singled out for comment. It is the betrayal of trust.

The instability of sales, service, luxury-goods, and capital-goods operations is certainly a contributory and perhaps a primary factor in all the elements of economic maladjustment.

The shift from agriculture to industry remains the major factor in occupational instability. Except for floods, freezes, insect pests, and droughts, agriculture on the subsistence basis is a relatively safe occupation. On the whole it provides only a low scale of living. Workers are attracted from this low-scale, stable occupation in agriculture during periods of good business to unstable marginal occupations in industry. This shift is always present when the standard of living is rising. Were general business reasonably stabilized, this change would be desirable as adding both to the market for and production of manufactured goods, thus being a primary factor in advancing the scale of living and giving a more general distribution of wealth. The shift from agriculture to industry is a contributory cause of business instability.

The reduction of profits at reduced plant output is greater when modern methods are employed, hence lowered output becomes an important cause of general business instability. Under modern operating conditions mechanical devices replace men in productive processes. As a result capital charges are a large proportion of manufacturing cost at full output, and these charges are constant and independent of the volume of output. The charges due to direct materials and labor are small in comparison, and do vary with the volume of output. In contrast, under older methods in industry capital charges were small, and direct labor was the largest item in manufacturing cost. Under these conditions as output decreased, the labor charge, an important proportion of cost, decreased in proportion.

Certain general considerations apply to the technological causes discussed in this report. As productive processes become more mechanized, more efficient, and less dependent upon direct labor, dependence on the rewards for productive operations as the primary means of distributing goods becomes less automatic and certain. There are perhaps other factors and relationships concealed within this situation which have not been isolated. The subject is of the utmost importance.

For a modern plant in which the variable cost items, labor and material, are small, and the fixed charges are large, it will be found that at full capacity the profit is greater than for the older methods of operation, but the break-even point where sales and cost are equal occurs at a higher point of production. The losses when operating at reduced capacity become proportionately quite large as production is decreased. As a result there is a tremendous pressure on the business to maintain output, which tends to expand and elaborate the selling organization.

Unstable relations between price and supply of goods appear in a highly mechanized industrial economy. That is, the response of output to price changes is sluggish under modern methods where fixed charges are a relatively high proportion of cost. This situation is made clear by a consideration of the theoretical extremes. If the whole cost was made up of the variable item wages, it would become unprofitable to operate so soon as the selling price dropped to the level of the cost. On the other hand, if the whole cost was made up of the non-variable item of fixed charges, operation would be justified at any selling price. In this situation a low price that entails a loss is still a smaller loss than if the plant were shut down. Hence when fixed charges are high, as they are under modern methods of industrial operation, a reduction in selling price of product does not necessarily cause a shutdown of even the least efficient plants.

From the foregoing considerations it would appear that the modern condition of heavy fixed charges is a primary source of business instability, without any apparent compensations.

The substitution of power for human effort is believed by some to be a primary source of unbalance. Careful study of this viewpoint does not reveal important influences not previously considered in this report.

Business-Performance Causes

Failure of profits to appear at the height of a boom is the traditional cause for the collapse assigned by some of those who hold to the view that the disturbing causes are primarily due to credit inflation. Modern productive processes tend to develop profits rapidly as production increases up to the point of diminishing returns. This tendency can be blocked by labor scarcity and consequent high labor costs due to high

wages and overtime, by inefficient, marginal labor, and by scarcity of materials. However, none of these influences appeared in 1929 in any important class of goods. Prices generally tended downward, indicating an increased difficulty in disposing of output. The only expense element tending to increase was that of selling. The reports of taxable incomes for the boom years give no indication of an increasing difficulty during that period in making profits from business and speculative transactions as a whole.

Lack of profit is a factor of doubtful importance as affecting any element of the present business cycle. Fear of the lack of opportunity for making profit, however, has an unstabilizing influence as it precipitates business inactivity.

False views as to the possibility of continuous profits affect business procedure adversely. In particular, there has been a tendency to consider net earnings of the most profitable period as being normal, and to pay them out in dividends on that assumption. Only in recent years has it become customary to adjust current policy to the movements of the cycle as a whole, recognizing that each industry has its characteristic history during the course of any cycle of business.

The point of view which gives importance to the business-performance causes demands attention. The basic assumption is that the illness of business as a whole is merely the sum of the ills of its parts. This assumption leads to remedies affecting individual industries, trade associations, etc. Many of these remedies appear to be useful and desirable but there is good reason for questioning the basic assumption.

A full view of the business cycle would suggest the need of reserves for dividends in poor times, for wages and salaries to maintain the organization, for unemployment funds, for the development work and plant improvement which can be carried on most advantageously during depression, and for working capital when business again appears.

To the extent that a business does not set up such reserves its operations become more unsteady and subject to wider fluctuations. If business in general follows this course, the total effect is to magnify the variations. This false view of continuing profits is a contributory cause of business instability.

Natural rhythms in the operating performance of individual industries can be detected. When these chance to coincide in their maximum or minimum phases, the total volume of business is affected thereby. This characteristic has been studied for 4 major industries: food, automobiles, textiles, and building construction. Of these, all except food exhibit marked rhythms, based on replacement periods. Furthermore, these rhythms appeared to culminate synchronously in the events of 1929–30. In view of all the other effective influences it is difficult to see how the natural rhythms of industry can do more than determine the timing of the cycle and affect its amplitude. They cannot be charged with a major responsibility for its occurrence. They are classed as an incidental factor affecting business stability.

Unbalanced relations between different branches of industry have been declared by some authorities to be the chief cause of business instability. As a major example the disturbed balance between agriculture and manufacturing has been cited. This factor is uncertain as a primary cause. Analysis at once turns to discovering the reasons for the disturbance of relationship. Several elements have been cited which upset the traditional corrective reactions of price, profit, and production, of supply and demand. Except for agriculture this factor is at the most contributory. Its presentation even is a description of a situation rather than a statement of cause and effect.

Attempts at price fixing and production control, private and governmental, are believed by some to have upset the natural economic compensations. Wheat and cotton stabilization, coffee, copper, and sugar control, the prorating of petroleum production, all are looked upon as introducing rigidity into an organism whose successful functioning depends upon flexibility and responsiveness.

Attempts at price fixing and production control, if not a primary cause of business instability, are a major contributory influence in the industries where they are practiced.

Excessive size of industrial organizations is claimed to be a specific cause of general business unbalance. It is asserted that the ability required to aggregate or consolidate a great unit of production and distribution is much less than that needed to operate it properly after it has been assembled. This is a reasonable assumption, and is supported by the present tendency toward dissolution and decentralization in many large industries, in the difficulties which many mergers have found in making expected savings, and in the present-day realistic attitude toward the profit possibilities involved. However, it is difficult to see how the history of the late boom and the present depression would have been greatly different if the largest industrial units had been smaller in size.

The great size of industrial units is a doubtful causal factor in business instability, but it does affect the severity of depressions.

Causes Relating to Savings and Investment

Inequality in the distribution of wealth is often advanced as a factor affecting business stability and the scale of living. The contention is that the failure to control the distribution of the standard of living reacts unfavorably on its degree and its stability, besides being undesirable in itself. Those who specially hold this point of view are usually disturbed with the manner in which wealth is accumulated, as well as with its total volume. Lending for interest has often been attacked, and also, more recently, profit, as distinguished from payment under free competition for personal services.

So far as these contentions are based on concepts of justice, they are outside the province of this report. Their presentation here is concerned with

their effect on business stability and the general scale of living.

Private ownership of natural resources, or of artificial monopolies, was the particular concern of Henry George. He questioned the justice and wisdom of permitting such ownership, whether of mineral deposits, fertility and site value, or franchises. However, the most unjust types of social organization are not necessarily unstable. For conditions to which it is economically adapted, slavery is stable as an institution and permits a stabilized rate of production and consumption.

It does not necessarily clog the economic processes to have large accumulations of wealth. If large sums are disbursed for personal service, the rich act as distributing channels for the social income.* There is more question of the effects of the savings and investments of the wealthy than of their expenditures.

The effect of concentrated income, as such, on stability seems to be doubtful.

Oversaving has been urged as the primary cause of business instability. Briefly the theory is this: In times when industry and commerce as a whole are operating on an even keel, neither expanding nor contracting, and neither adding to nor drawing on their surpluses, the acts of extraction, manufacture, and distribution of goods finance their purchase by the general public. The receipts from the monthly sales are all paid out in wages, salaries, and dividends, for materials and supplies, repair and replacement of equipment, taxes, insurance, and other services. If the firms and individuals to whom these sums are paid are likewise neither saving nor drawing on savings, but spending all they receive, the whole process is completely self-supporting. This is a commonplace of classic economics. Furthermore, expansion of activity can take place without upsetting the balance. For if, instead of paying out dividends, a company finds it expedient to spend its profits in expanding its plant and making additional expenditures for more material and increased labor for a larger work-in-process account, the increased expenditures go into the general pool of purchasing power to finance the initial purchase of the increased output, which then balances as before, but at a higher level. All this of course supposes that the product is salable and that increased labor hours are available. These are purely ideal conditions.

Many departures from ideal conditions come to mind. The most serious of them is the necessity for saving. Sad experience in an uncertain world has taught firms and individuals that they must save if they are to survive. But the act of saving withholds immediate purchasing power so that society, to the extent of its aggregate saving, does not buy the goods it has made.

These statements require qualification. The amount of "money," and the purchasing power which it represents, are not fixed, but variable. Another qualification, and an even more important one, relates to the use made of savings. If savings are not hoarded, but banked, they normally find their way into new investment, and this is their proper use. However, as savings increase in amount, their rate of inflow may be conceivably too great for the outlets furnished by obviously profitable investment, as described later. Uninvestable savings would then build up. This increase would aggravate the difficulty of selling the goods made.

The correctness of this theory, as concerns the present depression, hinges on 2 points. As a matter of fact, was there any failure in purchasing power previous to the collapse of September, 1929? As a matter of theory or fact, is it possible for funds which have been banked and thereafter loaned out for any purposes whatsoever to escape an ultimate use in the purchase of goods and services of some sort? A coincident drop in price and volume of manufactured goods, largely during the summer of 1929, points toward an increased difficulty in disposing of output and is favorable to the oversaving theory. On the other hand, it is not so clear that savings entrusted to banks can escape use in the purchase of goods or services, unless they are held idly in reserves. In 1929 funds were not hoarded, but banked, and loaned by the banks.

Overinvestment would appear to be possible, even if it can be shown that all funds saved find an ultimate destination in the purchase of goods and services. Oversaving may still be effective in the sense that it leads to an undue expansion of productive equipment without generation of a corresponding purchasing power to dispose of the output of that equipment. This theory has been convincingly stated by J. A. Hobson.* Business experience and available data tend to support the theory. Funds do appear to have gone unduly into physical investment in plant, office buildings, and hotels before and during the height of the boom, though the strictly productive investment appears to have declined before the peak. So far as the productive plant is concerned, the overcapacity at the peak of several important industries has been investigated by the U.S. Department of Commerce.** These studies indicate that in all major industries there existed at the peak of production an unused capacity varying from 10 to 30 per cent. It cannot be claimed that this unused

In the first progress report of this committee (see ELECTRICAL ENGINEERING for June, 1932, p. 373–9) it was contended that funds loaned on the money market were in part at least withdrawn from purchasing power. This contention has been denied by Professor Cassel. The countervailing arguments presented by Professor Eitemann appear to be convincing. No opinion in regard to this theory is given. The matter is left indeterminate and set apart for further study. Business experience appears to support it. Theoretical analysis makes it appear untenable.

* For a contrary view, but based largely on ethical grounds, see Thorstein Veblen's "Theory of the Leisure Classes."

* See, for instance, his "Rationalization and Unemployment Problem." Read also the picturesque and uncompromising pamphlet by David C. Coyle, "Business Vs. Finance," published by the author at 101 Park Avenue, New York, N. Y.

** See Bulletin of the Taylor Society, New York, N. Y., for June, 1932.

capacity was the most efficient, but it is clear that at the recent peak, marginal productive capacity was not used to the extent customary in previous booms.

There are, then, evidences of overinvestment or unwise investment in capital facilities as compared with the volume of production which consumers are able or wish to purchase. That it was a question of ability of consumers rather than their desire was argued previously. It does not clearly appear, however, that this excess productive capacity, resulting from overinvestment, necessarily slows up the flow of business. Why are not the production and sale of capital goods as effective as consumer goods in financing purchasing power? An abandoned automobile or factory seem to be in the same category. Each employed men and materials in its production, and in varying degrees in its later use.

The most evident difference lies in the fact that the now unneeded factory had formerly attracted workers, some from other factories, others from agriculture and the ranks of the unemployed. Industry was unable to sustain these workers, so they were compelled to make new connections or be unemployed. At least, therefore, there is involved a social dislocation which is not easily or quickly adjusted; and during the process of adjustment there is a failure of purchasing power.

It is clear that unneeded capacity lowers the general scale of living. It turns productive activity into impersonally wasteful uses. Over investment seems at first sight to be a much more direct and serious cause of economic evil than it proves to be on careful analysis. Possibly there are elements involved which have not been clearly distinguished.

The factors relating to the accumulation of savings and their flow into investment are of great importance. Inequality in wealth in itself is not so determinative as the way in which it is used, whether in consumption, social expenditures, physical investment, or speculation. Much of the importance in the question hinges on future trends which are not clearly defined. An unrestrained profit system works most effectively in the situation of virgin territory with undeveloped resources, or, with less certainty, when rapid technological advances require new investment. Secular changes in these elements, in world industrialization, and in population growth will severely tax the profit mechanism in its present form. These factors probably affect stability primarily and adversely, contribute to delay in a rise in the general scale of living, and affect primarily and adversely the distribution of wealth.

Overinvestment, or unwise investment, is a probable primary cause of instability, and certainly a contributory bar to an increase in the general scale of living. Finally, the resulting destruction of capital is a clumsy and wasteful method of regaining balance.

A slackening in the opportunity for profitable investment has been suggested as a present or imminent condition either on a temporary or a permanent basis. The discussion given in preceding paragraphs indicates the desirability of a balance between savings and profitable investment. That the ratio between the rate of savings and the rate of investment is highly significant is becoming generally recognized.*

That there has been a permanent slackening in opportunity for profitable investment is a highly dubious conclusion, but is worthy of thought, nevertheless. An obvious factor is the slackening of population growth, due to the curtailment of immigration and the inevitable flattening of the curve of natural increase. Such a large increase of investment in the future will not be needed to care for increased population. Another evident factor is the approach to complete development of our natural resources, and the rapid development of competing resources in more recently explored parts of the earth.

Allusion has been made to a serious and significant fact which lends weight to these speculations. This last boom was the first major one in which industry as a whole did not receive orders in excess of its capacity. Deliveries were not greatly delayed at the peak. It was a "buyers' market." For the first time there was ample equipment and labor with which to meet the extreme demands of unrestrained business enthusiasm.

There is one large and hopeful chance for a renewed demand for physical investment. This will become a reality if our economy is recast to provide increased purchasing power for the millions who are able and willing to render effective service, but who either temporarily or permanently cannot secure employment. An important factor in providing this increased purchasing power will be the higher wages which will prevail as soon as it becomes economically sound to pay them.

If overinvestment in enterprises for the production of consumer goods is a factor tending toward business instability and disturbance of the scale of living, any considerable permanent slackening in the opportunity for such investment would have an identical effect.

Economies through managerial efficiency are particularly upsetting to the balance between production and purchasing power. While great changes in production methods took place in the last generation, they were commonly dependent on the development of new and more expensive equipment. This industrial progress furnished a continuing use in investment for the savings derived from that progress. Frederick W. Taylor, who initiated the industrial efficiency movement in the 90's, made full use of the latest improvements in mechanism and apparatus. However, he was particularly concerned with the great efficiencies to be obtained by the rational use of existing mechanisms. His principles have had their most rapid expansion in the last decade, during which time there has been a great increase in efficiency, resulting in corresponding profits. To the extent the profits resulted from improvement or change in management policies,

* The 2-volume work on "Money," by J. M. Keynes is largely an exposition of this thesis.

they did not generate an outlet for savings in any corresponding volume of new physical investment.

Improvement in managerial efficiency appears to be a contributory cause of unbalance, a primary beneficial factor in a possible rise in the scale of living, and of doubtful effect on the distribution of wealth.

FINANCIAL CAUSES

Speculation is a commonly assigned cause of business and economic troubles. It is a conspicuous feature in every business boom. Two questions may properly be asked. Business activity and speculation have always gone together, but need they be joined? Is speculation itself a cause of collapse, or only a symptom of more fundamental disorders?

The first question may be resolved into the more basic inquiry as to whether there was anything essentially speculative in the physical volume of business during the years 1928 and 1929. So far as concerns goods for human consumption and enjoyment, this query may be answered unhesitatingly in the negative. There are 2 ultimate limitations on the economically justifiable production of material goods: The requirements that unreplaceable natural resources must not be squandered, and that enjoyable leisure must not be sacrificed by producing products to be wastefully consumed. As regards the first limitation, it may be asserted with confidence that, as a whole, our resources are not being squandered. The second limitation, that of leisure versus goods, is primarily a question of values, and so is in part outside the present field of discussion. It may properly be noted, however, that even with business at its best there were millions of American citizens existing on a very low scale of living.

In general, banking policies, whether resulting from the practices of the business, or from governmental regulation or its absence, have a serious primary effect on business stability.

The second question, whether speculation is a cause or a symptom, is more difficult to analyze. From the business and industrial point of view the history of the last boom may be stated as follows: The unparalleled improvements in machinery, processes, and management methods in the period since the war resulted in a large increase in productivity of existing manufacturing establishments and the building of additional plants. For a time the provision of the improved and additional equipment absorbed the large available profits, furnished employment in the production of capital goods in new investment for labor otherwise displaced, and thus offered a market for the increased flow of consumer goods.

Speculation is always latent in our social structure. In its recent outbreak it was, in the first instance, a result of other causes, but it quickly became an enormously exaggerated unbalancing factor on its own account. As such it destroyed business stability.

As the provision of new equipment approached saturation, however, the situation changed. Increased output was maintained and profits were high, but there had been no proportionately increased returns to labor and to those in the lower-salaried positions during this period of expansion. Nor did those receiving dividends and the higher salaries choose to spend in consumption in full amounts received. They sought further investment instead. There was thus a failure in purchasing power to match the increased production of consumer goods. This situation was masked for a time by the rapid expansion of instalment buying but became evident when its source of credit had been stretched to its limit.

Credit expansion and contraction, as determined by banking policy, has a primary effect upon the expansion and contraction of business, and thus on its stability. That it is a direct cause of speculation, and maintains that fever after it is generated is undoubted. That it exaggerates speculation, which itself exaggerates original business instability, likewise seems clear.

The evident adequacy of existing plants, and the temporarily high returns from their operation, led to a condition in which the purchase of the securities of established enterprises was much more attractive than the building of new ones. This process was stimulated and expanded by the desire to deal in securities as commodities, as something to be bought and sold at a profit. Thus vast accumulations of savings, both large and small, were directed into speculation instead of new investment. This stimulated the real-estate market and the investment-banking business, and led to the floating of immense and valueless issues which represented no physical expansion whatever, but merely revaluation of properties at highly inflated levels, based upon expected earnings. Speculation is thus seen to be an almost inevitable result of the assumed oversaving and overinvestment.

Investment banking has been subjected to much criticism for the part it has played in unsettling business. It is charged with misleading the public through the sale of worthless securities. Its relationships are sufficiently described in the preceding paragraphs. The extent to which responsibility can be placed upon it and accepted by it, or the degree and kind of control which can and should be imposed, are matters relating to remedies rather than causes, and will therefore be left for later consideration.

Commercial banking policy in general may be an unstable element. Unfavorable effects may result from policies customary in business and permitted by legislation, or from those forced upon it by governmental regulation. In either event legislative control appears to be a necessary factor, even though at times it may be unwisely applied.

Certain governmental provisions have, or may have, a primary stabilizing effect. Among these are the semi-official functions of the Federal Reserve

Credit inflation is one of the first factors affecting business stability which needs control. It cannot be maintained, however, that it is the only cause of business instability.

banks. Unfavorable elements of governmental regulation are seen by many in state legislation against branch banking, which tends in some states to foster the growth of weak local institutions in small communities. Still a third class of governmental effect is seen in the laxity of laws in some states. There are other banking practices of a recognized sort, some optional, others inescapable, which act as elements of unbalance.

Chief among the apparently inescapable factors is the necessity for selling securities by the banks during and after the collapse of a boom to "maintain a liquid position," so that the banks can meet the lawful demands for cash on the part of their depositors. Such selling embarrasses individual borrowers and lowers security prices. Both practices tend to hasten and accentuate the collapse as much as speculation hastens and accentuates the boom. The most effective act of commercial banking practice is the control of credit, involving the defensive act of contraction and the more positive acts of expansion and inflation.

Installment buying is a primary factor in delaying the return to stability with no apparent permanent effects on the scale of living or equality of distribution.

Credit expansion and contraction is a normal banking function, whose proper and easy performance was the original purpose of the Federal Reserve banking system. Credit expansion actually adds to the funds available to business by the process of making loans, actually without a corresponding decrease in resources for the banks. To facilitate the normal process, of making loans, the Federal Reserve system arranges for the pooling of the reserves of the member-banks, and also for the rediscounting of the paper on which its loans are based. The latter act, in particular, greatly increases the ability of a bank to make loans, as it promptly receives the amount of the principal back from the Federal Reserve bank, as well as enjoys the increased deposits resulting from the loan.

It is evident that the total effect of individual banking policies in making or refusing loans at lower or higher rates has a marked effect on business expansion and contraction. It is, furthermore, evident that the rediscount rate of the Federal Reserve bank has a still more fundamental and controllable effect of the same sort.

That this effect is not directly proportional to the numerical values of the pooled reserves or of the discount rate is evident from the present situation. Psychological factors are effective also. Even that more technical branch of economics called finance must be classed as a "social science," with all of the implications which that term comprehends.

Credit inflation is a term hitherto applied to credit expansion carried to an extreme. Recently it has been proposed to assign to it a more definite and measurable meaning to distinguish it from normal expansion and contraction.* In considering these concepts, it should be borne in mind that short-term loans usually reappear in checking accounts. To the extent that business operations are financed by such self-liquidating loans, these 2 elements should tend to balance each other. It is likewise asserted that the time deposits of all banks—which represent savings—should show an equality with the long-time paper, mortgages, stocks, bonds, and the like. This is a reappearance, from a new angle, of the principle that savings should equal investment. It is more fully discussed in Keynes's treatise on money.

According to older points of view—here Keynes must be included—credit expansion and contraction are relative factors. All bank loaning operations represent its existence in some degree, and it would never sink to zero except on the extinction of all business not done on a barter or gold basis. The reason for the existence of the banking system would vanish with its extinction.

Harwood contends that it is desirable to keep credit expansion based on investment type assets as near zero as possible. When so kept it would appear that: (*a*) the rate of saving is equal to the rate of investment; (*b*) there is no debt structure being built up on over valued as sets; (*c*) speculative profits and losses are currently wiping each other out, leaving the returns from industry to be distributed more nearly on the basis of competitive reward for services rendered, whether by management, labor, or capital;** (*d*) the general price level would permanently adjust itself to the slowly changing gold level, undisturbed by credit inflation; and (*e*) the growth of security prices would be a measure of the actual saving of physical goods and their application to physical investment. Under present conditions the increase in values represents principally the inflation of funds available for their purchase.

In this view, any cumulative excess of investment over savings is a fallacious and an unstable condition, self-generative of further inflation, and only to be arrested by its approach to the limit of gold reserves, as in 1920, or by a general recognition of its top-heaviness, as in 1919. While the general position taken by Harwood seems to be useful, his statistical work has been criticized.

The monetary factor is a primary cause of business instability, and a contributory cause of an unsatisfactory scale of living and of inequality in distribution.

Installment buying is classed among the financial causes because on any large scale it depends ultimately on the extension of banking support through credit corporations or otherwise. The crucial aspect is the method of financing. If bank credit is employed, it may be

* See particularly "Cause and Control of the Business Cycle," by E. C. Harwood, Financial Publishing Company, New York, N. Y.
** The return to capital will approximate the "natural rate" of interest. There would seem to be no effect on the returns from natural and artificial monopolies.

unfortunate in its effects, for it provides purchasing power that has neither been earned nor saved. If, however, the credit represents savings, the situation may be sound.

Monetary factors are of evident importance in economic disturbances. They manifest themselves through variations in the general price level, that is, through changes in the value of the dollar. These changes are due in part to the factor of credit inflation and deflation, already described, and in part to the relative value of gold on which our currency is based.

While no technical description of the theory of prices, on which experts disagree, is given, it is still clear that prices must be some function of the total funds available, and that these funds are composed of credit in various forms, on the one hand, and of currency, on the other. The currency is for the most part gold-based. Credit is gold-limited, but not gold-based.

A part of the difficulty surrounding the subject arises from the fact that the factors of currency and credit have not been separated, and that there are differences of opinion as to the nature of the credit factor.

There is no dispute as to the seriousness of extreme variations in the price level. As the level rises, persons with fixed incomes suffer hardship, creditors are paid in money of lower purchasing power than that which they lent, and wages tend to lag behind prices, though employment is good. On the decline, debtors find it hard or even impossible to pay in costly dollars debts incurred during inflation. On the other hand, creditors who are paid gain thereby, those with fixed incomes enjoy an advantage for a time and prices tend to fall faster than wages, though employment is scarce.

Foreign indebtedness is an important contributory cause of instability, and a primary cause of some degree of lowering in the scale of living. It also appears as an agent in the redistribution of wealth as between the investing and the manufacturing classes.

On the whole, the variation in the price level tends to enrich the more astute of the investing class, who are accustomed to reckon on and adjust themselves to its variations. In its extreme variations, as in the drop of 1920–21, and again from 1929 to the present, the creditor class becomes involved in the distresses of the debtors and no one profits.

If credit inflation could be controlled, and the price level maintained by the relationship between the productive costs of gold as a commodity and other commodities, changes in the price level would not be as serious as they are now. The prime advantage of gold as a currency base lies in the large volume of permanent monetary supply as compared with annual accretions. Price fluctuations based on this factor alone would therefore probably be of such slow effect that all classes of society could adjust themselves to it without hardship.

War inflation is by all odds the most serious form of monetary disturbance. It is primarily a credit factor, and only secondarily a gold phenomenon. No great war has been financed without credit inflation. If we would avoid this greatest cause of instability, of scales of living reduced below the attainable standards, and of unfortunate spreads in the distribution of wealth, war, with its accompanying inflation and its inevitable deflation, must be prevented.

The financial causes and factors relating to economic instability are of primary importance. While the business and profits and the savings and investment factors set the stage, credit inflation furnishes the energy for destructive speculation, and unwise banking weakens the structure and broadens the collapse.

The burden of debt is a factor whose effect is obvious and directly felt, but whose elements are more numerous than appear at first sight. The total of public and private debt in the United States is enormous; a recent estimate places the total of industrial indebtedness (bonds, mortgages, bank loans, etc.) at over $200,000,000,000. While such sums are very great, their significance can be exaggerated. In substance, they state the total of a certain form of evidence of ownership, the property itself being under the management of others than the owners with the expectation that they can "service the loans" (pay interest and pay installments on the purchase of the property) and still have something left over. This situation might not be unmanageable except as the change in the value of the dollar makes it so. Most of these obligations were undertaken at a much higher price level. It is the variation in the monetary factor which makes the burden unendurable.

Indebtedness under these conditions has one effect of its own as well. It makes it difficult or impossible to come to a profit basis during a depression by reducing wages, salaries, and other variable expenses. In general, the burden of debt has the same effects as deflation under the monetary factor.

Foreign debts are a disturbing factor, whether in the operations by which they are incurred, their continued existence, or the attempts made to service and collect them. But their effects appear to be different from purely domestic ones, in that they operate through the mechanism of international exchange, and affect or are affected by direct political considerations.

The normal difficulties of war debt payment have been accentuated by the drop in the price level, the same as for private domestic debts. This is reflected in part by drops in exchange value of those nations which have gone off the gold standard.

The difficulties of repayment are partly political and partly economic, aside from the change in values. We have no mechanism for receiving large payments. We cannot be paid in gold, we are unwilling to receive the equivalent in an excess of imports on account of its effect on domestic industry, and foreign credits or even currency are useless ex-

cept as they can be exchanged for gold or goods, or absorbed into the "invisible items" of the international balance sheet. This subject is only touched upon; here the concern is primarily with domestic questions.

There is no doubt that the collapse of the European financial structure in 1931, after this country had made unwise loans to support it, had a serious effect on our own condition and possibilities of recovery.

During the war we loaned our allies goods, primarily, taking paper in return. In the periods since the war our net export of goods has tended to vary with our net export of capital. Fundamentally this means that the producers of exported goods are paid by the domestic buyers of foreign loans. Viewed in this way it is a domestic transaction, but with the purchaser holding title to future payments instead of consuming the goods. The process is reversed when, as, and if loans can be paid for by an excess of imports. In that case the domestic purchasers and consumers of foreign goods reimburse the holders of foreign bonds, which are thus retired. To the extent that this normal procedure is followed, the transaction still remains a domestic one.

By its very size agriculture is a preponderating factor in the market for goods, and, for that reason, its well being is vital to national prosperity. However, it is inherently unstable, and further, because of its peculiar exposure to the evils resulting from war financing and war production policies, it is in a situation of distress which is a primary cause of the lowering of the attainable standard of living, and in the uneven distribution of wealth.

But this normal method of repayment is almost impossible for us, both politically and practically. The repayment and servicing of large scale foreign loans requires changes in the balance between our domestic and foreign sources of supply which we are unwilling, and may be unable, to make. The net result of the difficulty in repayment is therefore a domestic shift in wealth distribution from the American lender to the American producer of export goods, and since these goods were consumed abroad, they are subtracted from the possible total of domestic consumption.

Agricultural Causes, Too, Must Be Considered

The post-war deflation bears with special severity **on agriculture,** particularly that devoted to the staple cereals. During the war the collapse of European production stimulated our own. The prices of farm products were artificially set to prevent excessive profiteering. At the same time official encouragement was given particularly to the production of foodstuffs. As a consequence younger and more enterprising farmers took over larger and larger acreages from the older owners, usually on mortgages at the prevailing inflated prices. This policy was spectacularly effective in its immediate results, but has left the farmers with an undue proportion of that burden of debt already described. As investors in farm mortgages, banks and insurance companies are sharing in the burden.

The results of war inflation in agriculture are a primary cause of instability, of a lowering of the scale of living, and thus of an inequality in distribution as between agricultural and other classes who are less directly affected.

New producing territories and new productive methods have played a part in agricultural distress, although the per capita production of farm products in the United States has been decreasing since 1915. Wheat and cotton, for example, are not only feeling the impact of the expansion of new territories, but also that of new varieties and processes. These circumstances and conditions are among the causes responsible for present economic conditions in this country.

Crop surpluses have been another disturbing factor. For the years 1927 to 1930 the annual production, in general, of the great staple crops has been high, although not the largest crops on record. In wheat, however, the average world production for these 4 years was over 4,600 million bushels per year, as compared with an average of less than 4,000 million bushels annually for the preceding 6 years. The production of the U.S.S.R. is included in these figures. The principal causes of the surpluses in the United States were the reduction of consumption and loss of exports.

Agriculture as a business has certain difficulties of its own. It is burdened with too high land values, it has been injured by loss of exports, it has suffered since 1929 from low prices for its products, and it must operate under a wide range of production costs. In the case of foodstuffs it meets a comparatively inelastic market. Production cannot be accurately gaged in advance, due to the uncertainties of weather and crop-influencing conditions. Agricultural output is under control through only one factor, and but once a year, at planting time, which is many months before harvest. During the growing period conditions may and do arise which indicate acreages quite different from those planted, provided they could have been foreseen. Staple agriculture is essentially unstable.

Agricultural methods of operation are so complicated and under the best of conditions so completely mechanized that farming cannot absorb the unemployed released from industrial occupations, except on the basis of subsistence farming, a standard of living which would tend to destroy everything desirable in our social structure. To be a source of national strength, agriculture must be treated as a manufacturing industry.

The various governmental acts bring serious forces to bear on the economic problem, but in so diverse a way that it is not possible to evaluate them.

Governmental Causes

Tariffs interfere with the free flow of goods from country to country, and are thus an element in preventing the attainment of a natural, world-wide equilibrium. It is commonly assumed that such an equilibrium is desirable. But equilibrium assumes a tendency toward the leveling of the scale of living in proportion as special advantages of different areas tend to diminish, as is the case at the present time. At this particular stage of industrial development and of the diffusion of techniques and mechanisms, the first result of ideal free trade conditions would appear to be the emergence of the scale of living to the position of being the decisive element in world competition. In such a situation our own scale of living would be inevitably depressed below what is physically attainable.

World forces in actual effect at the moment tend to put a new aspect on the tariff question. It is appearing as a tool of conscious social control, rather than as a support for special interests. In proportion as this change can be recognized and assisted, this factory may be made a primary element of stability, and contribute to a raised scale of living.

The single finding which the committee is willing to support at this time, drawn from the presentation of causes and remedies, is that no one all-inclusive cause can be designated as the forerunner of business recession, nor can any one all-inclusive remedy be found as a preventative or cure. The situation that this finding presents should occasion neither surprise nor discouragement. Emphasis is merely given to the accepted fact of the complexity of our business and industrial structure, and to the interaction of economic forces. The problem of social and economic control is of such magnitude that its solution will be a major event in the history of civilization. The project cannot, and must not, be approached from any inferior estimate of difficulty or extent.

Restraint of business by government interferes with free adjustments internally as do tariffs externally. Among the governmental interferences may be mentioned the anti-trust laws, railroad rate, and other forms of control by the Interstate Commerce Commission, and the attempts to control prices of commodities artificially, as wheat and cotton prices by the Farm Board. As to the control of prices, when the government seeks to fix the price of any commodity, that very attempt prevents the setting of proper prices, except under conditions of national emergency, such as war.

Other forms of governmental authority have pointed to similar complexities in the exercise of arbitrary control, and give support to the view that such policies, even when unavoidable, are at least contributory causes of unbalance.

The burden of taxation is annoying in prosperity, but scarcely endurable in times of depression. In part it is a reflex of the tendency to spend a growing proportion of our income in various forms of social expenditure, instead of in personal consumption. To the extent that this choice is consciously made, and the expenditures are economically administered, the increased taxation is not only inevitable but desirable. In part the present burden of taxation is derived from war financing and war obligations. Finally, the burden of taxation has been multiplied by the deflation since the war.

Under the present fiscal ideals which endeavor to equalize the volume of taxation over good times and bad (though with little success), taxation during the depression is a handicap to recovery so far as the psychology of recovery requires the attainment of profit conditions.

The burden of taxation would appear to be a contributory cause of business unbalance and a factor in the distribution of wealth. It affects the average scale of living in the sense that it may divert purchasing power from personal to social consumption which may or may not be preferred.

Public construction in municipal, county, state, and federal undertakings, is sufficient to make it an important element in the total volume of business. To the extent that the fluctuations of public construction coincide with those of private business, it would appear to add to those fluctuations. To the extent that the 2 classes are out of phase they will tend to diminish the amplitude of the total variations. This is merely the obvious primary effect. There are doubtless important secondary effects not clearly recognized.

The present coincidence of the variations in public and private activity accentuates as well the fluctuations in employment, and concentrates public expenditures in the period when costs are highest.

It is evident that any method of improving this situation will have to take into account the favorable period for taxation.

Summary and Closure

By way of summary, the committee restates the fact that the causes of business instability naturally fall into the 7 groups presented in this report, and on the whole, the items in each group are so related as to lead to the surmise that the effective remedies may be more or less in common, that is, the rational structure presented by the causes suggests a corresponding structure of appropriate remedies.

This second progress report should be considered as superseding its predecessor of a year ago for the reason that it indicates the direction and quality of thinking of a year of intense business stress. The next effort of the committee may well be to select and present those elements of remedial programs which seem feasible and practicable, and which promise to integrate into a program of social and economic control. This integration will be attained only through a slow evolutionary process.

Neon Tube Characteristics

Information supplementing and confirming the studies of voltage and current waves in neon tubes published in a previous issue of ELECTRICAL ENGINEERING are presented herewith. It is shown that there is a peaked starting voltage at the beginning of each wave, the current is practically zero at this point, the time during which the current wave remains at zero is negligible for a properly processed tube, and flickering will occur if the current remains at zero for even one-third cycle. Information on transformer regulation also is given.

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In a recent article by Claude M. Summers "A Theory of Neon Tube Operation," appearing in Electrical Engineering for November, 1932, p. 772–5, certain statements are made which it is believed might be elucidated considerably by means of, additional oscillograms, curves, and explanations. The statements which were made in the previous article, and the supplementing discussions thereon follow. These discussions refer to cold cathode gaseous conductor tubes.

On p. 772 of the previous article it is stated that a considerably higher voltage must be applied to a tube in order to start it, than the voltage which is subsequently required to maintain the current flow.

In laboratory practice "starting" and "burning" voltages are common terms, and their relative values may be seen from the oscillograms reproduced in Figs. 2 and 5. In Fig. 2 the ratio of these 2 values is about 1.77; in Fig. 5 the ratio is 2.08. As has been pointed out, however, these ratios vary with the total length of the gas column, the number of electrodes therein, the material of the electrode, the nature and pressure of the gas, and many other factors.

Time Relation of Current and Voltage Waves

The article in the November 1933 issue of Electrical Engineering also contains the statement that the "current wave crosses the zero axis inside the envolope of the voltage wave." By reference to the line AB on Figs. 1 and 4, in fact on all the oscillograms shown, this is seen to be the case, and an interesting fact is here disclosed: it is, that there is no angle of lag or lead, or phase displacement, between current and emf, that is to say, under the ordinary conception of the term "phase displacement." It is known, however, that there is a power factor differing from unity in the high voltage circuit of the supply transformer.

There is found here the case of a circuit in which the power factor—that is the ratio of the watts to the volt-amperes—does differ from unity without any displacement of phase; in such a case, while the current and emf are in phase with each other, but are distorted, the alternating wave cannot be replaced by an equivalent sine wave, since the assumption of an equivalent sine wave would introduce a phase displacement of value $\cos \phi = f$, wherein the angle ϕ is indefinite as to sign.

Such a condition arises from the pulsation of impedance or resistance present in any (high pressure) gaseous discharge tube. The apparent impedance of such a tube depends upon the current passing through it; that is, the apparent impedance of such a tube is

$$Z = \frac{\text{potential difference between electrodes}}{\text{current}}$$

and is, in general, high for small currents, and low for large currents. Thus in an a-c circuit containing such a tube, the apparent impedance will vary every half wave of current between a maximum value at zero current and a minimum value at maximum current, thereby describing a complete cycle per half cycle of the current.

From these considerations it is possible to calculate the power factor, but this problem will not be considered further here.

Time Length of Current Zero

Additional information also can be thrown on the statement made that the current in a tube circuit is actually zero for a finite time.

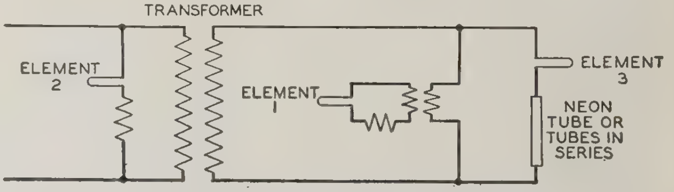

Fig. 1. Connection diagram for neon tubes and transformer, and oscillograph elements used in obtaining records shown in Figs. 2–7

Element 1 measures voltage across tube and shown as upper curves on Figs. 2–7

Element 2 measures primary voltage waves supplied to transformer and shown as middle curves on Figs. 2–7

Element 3 measures current through tube and shown as lower curves on Figs. 2–7

Transformer is of high magnetic leakage type

Written especially for Electrical Engineering. *Not published in pamphlet form.*

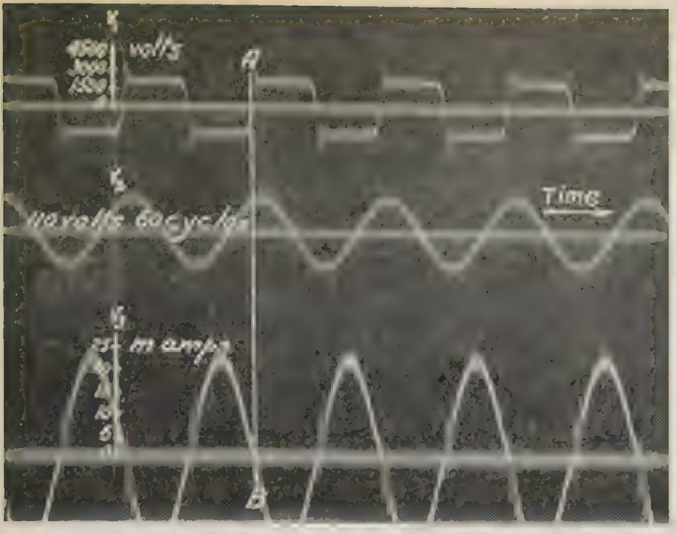

Fig. 2. 10-ft 15-mm outside diam neon grid. Tube satisfactory

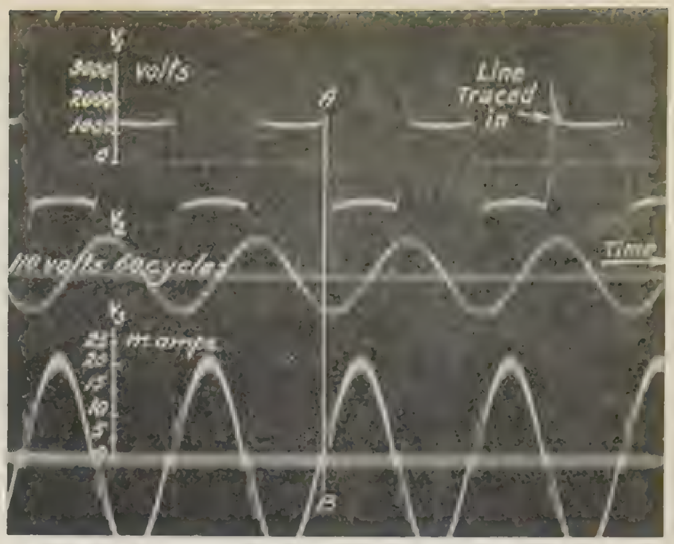

Fig. 5. 10-ft 15-mm outside diam neon-mercury grid. Tube satisfactory

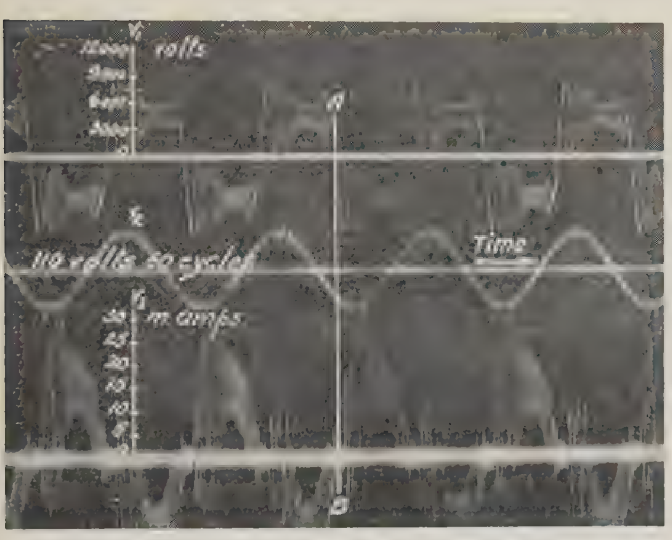

Fig. 3. 2 10-ft neon grids in series. One "wormy," other satisfactory

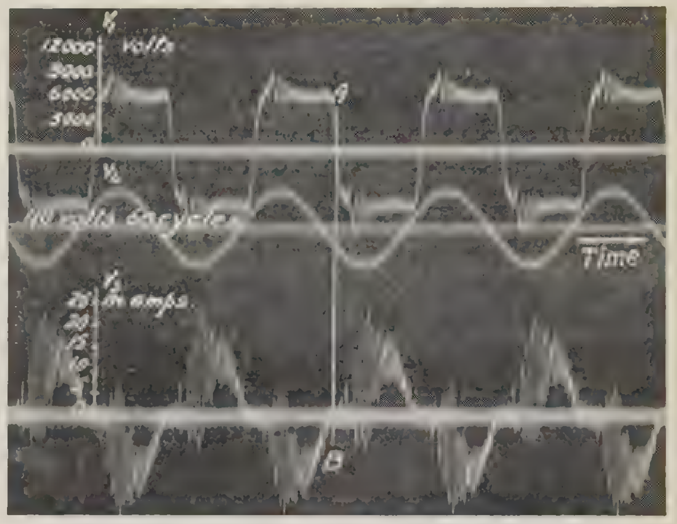

Fig. 6. 30-ft 15-mm outside diam neon-mercury grid. Flickering

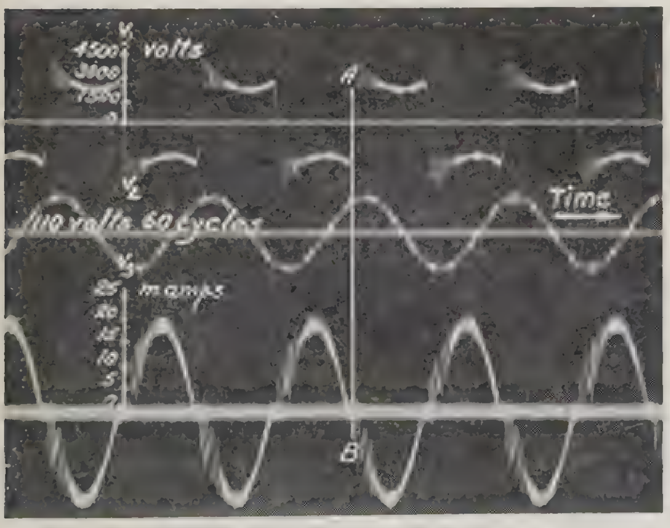

Fig. 4. 10-ft 15-mm outside diam neon-mercury grid. Tube satisfactory

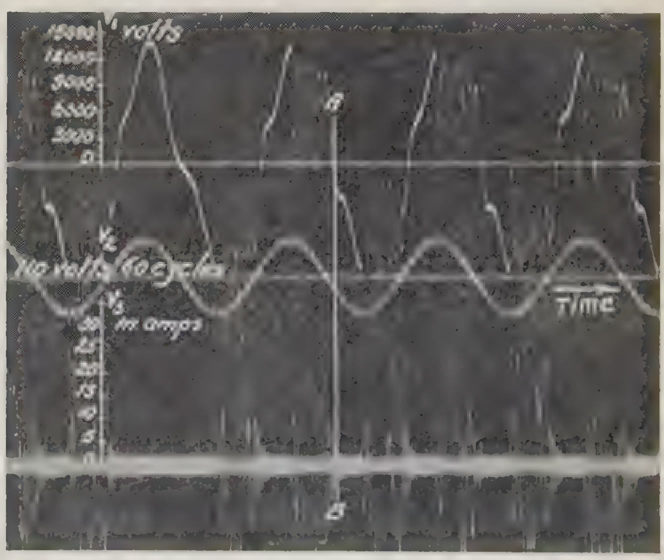

Fig. 7. 30-ft 15-mm outside diam neon grids. Flickering badly

Figs. 2–7. Oscillograms of neon tube voltage V_1, tube current V_3, and transformer primary voltage V_2. Connections are as shown in Fig. 1

In a properly processed tube, while the current is necessarily zero during its passage across the zero axis, and while this time of passage is, mathematically, of finite value, this time interval is so short that the resulting darkness of the tube is not ordinarily visible to the eye. Oscillograms from such properly processed tubes are reproduced in Figs. 2 and 5, and from an inspection of the current waves thereon it will be apparent that the percentage of the time cycle during which the current wave remains on the zero axis is negligible.

This condition is *not* present, however, in improperly charged tubes, nor in the case of tubes fed from improperly designed transformers. Under either of these conditions the time which the current wave spends on the zero axis may be an appreciable proportion of a half cycle, resulting in "flickering" of the tubes. This is shown in Figs. 6 and 7, the lower curve being in each case the current, and the upper curve the voltage wave, while for comparison, the primary voltage wave fed to the transformer is presented in the middle curve.

Period Required to Produce Flicker

The statement also is made that no ionization for a half cycle will produce flicker. It is not necessary, as above shown, for a tube to be "out" for a half cycle or longer to produce "flicker." By reference to Figs. 6 and 7, which were taken from tubes which were flickering badly, it will be observed that the current wave remained on the zero axis less than $^1/_8$ of a half cycle; in fact, a considerably shorter period than this will produce objectional flicker.

General Wave Form of the Voltage Curve

In the previous article the theoretical wave form (along its operating limits) is shown to be a flat-topped curve, concave upward.

Such a curve, or approximations to it, are in fact, obtained in practice, as shown by Figs. 4 and 5, which were taken from tubes containing gas at 6 and 9 mm pressure, respectively; but the "smoother" a tube operates, or in other words, the greater the ratio of the striking voltage available, to the burning voltage required, the greater the departure of the actual voltage wave from the theoretical concave wave.

Thus, in Fig. 2, is seen a straight-line flat-topped wave (not concave) obtained from 10 ft of tubing containing gas at 12 mm pressure, and fed from a transformer capable of supplying 30 ft of tubing. Such straight-line waves are indicative of long life of the tube, and safe operation of tube and transformer.

Strain on Insulation Due to Flickering

Another statement in the previous article is that to great a length of tubing places a severe strain on the transformer because the high frequency oscillations are near the peak of the open circuit voltage of the transformer and are prolonged for a half cycle. This statement might be modified to include a strain on any part of the secondary circuit, i. e., the tubing and high voltage wiring, and of a value much greater than the open circuit voltage of the transformer if sufficient electrostatic capacity is present.

In Fig. 7 is shown sustained high frequency oscillations after the peak of a half cycle, and Fig. 3, similar oscillations during the first half of a cycle. In view of this visual proof of harmonics present in such tube circuits it will be evident that the introduction of condensers or other accidental capacity into such circuits may cause immediate breakdown of the insulation of the system; and it may be pointed out in this connection that the capacity of a condenser cannot be even approximately determined by measuring the voltage across it and the current through it, if there are higher harmonics present in the circuit.

The High Magnetic Leakage Type of Transformer

The term regulation used with reference to the ordinary type of power or lighting transformer implies the small variation in voltage throughout the current range of the transformer; when used with reference to the high magnetic leakage type of transformer, however, it has become the custom to consider regulation as the relation between the large voltage change with nearly constant current output. The latter type of transformer is, of course, the type at present used for gaseous tube supply.

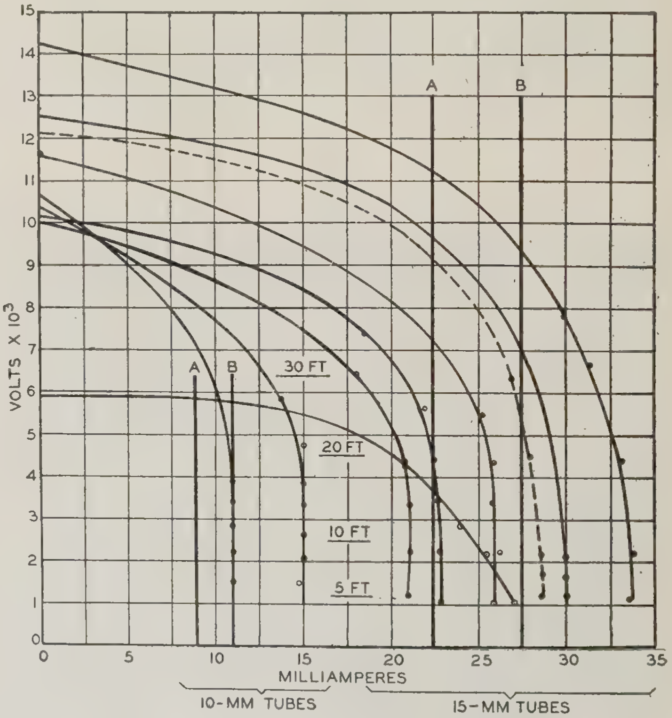

Fig. 8. Transformer regulation characteristics

Two curves for 10-mm outside diam tubes; 6 curves for 15-mm outside diam tubes. Lines *A* and *B* represent lower and upper limits of desired current with varying tube lengths; shown for both 10-mm and 15-mm diam tubes

In Fig. 8 are shown 6 curves of regulation characteristics of a number of different makes of such transformers designed to operate up to 40 ft of 15 mm outside diameter neon tubing at the desired input of 25 ma. Two curves also are shown for transformers designed to operate up to 20 ft of 10 mm tubing at 10 ma. The lines A and B, shown for both diameters of tubing, represent the minimum and maximum values of desired current with varying tube length.

A theoretically desirable regulation curve would, for example, run vertically up the 25 ma ordinate from zero to maximum tube footage, and then follow the abscissa at that voltage to zero current or open circuit voltage, thus subjecting the transformer windings, the high voltage distribution system, and the tubes themselves, to the least possible maximum voltage.

However, owing to the fact which has been discussed above, that $1^1/_2$ to $2^1/_2$ times the "burning voltage" of a given tube must be supplied as "striking voltage" in order to re-establish the arc at every alternation, this excess voltage must be derived (principally) from a rising regulation characteristic; and this characteristic therefore takes the general form shown in the curves. From this it may be observed that, at periods of no current through the tube, the voltage rises from say 6,500 volts at 25 ma on 30 ft of tubing, to 12 or 13,000 volts at no current, or open circuit.

Radio Aids to Air Navigation

Equipment that is believed to embody new and interesting features is described in this article. Further refinement in detail and further testing are necessary, however, before the apparatus can be applied to regular service. Its ultimate adoption will depend, of course, upon its ability to compete with other systems of air navigation from the standpoint of application, accuracy, simplicity, reliability, weight, size, and cost.

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APPLICATION PENDING

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RADIO has played an outstanding part in the promotion and maintenance of regular scheduled flight and safety in air transportation. In a relatively short time it has become an essential means of communication and navigation, and is steadily increasing the number and extent of its applications. It is particularly useful because it furnishes the navigator with reference axes and points.

One- and two-way communication have placed at the disposal of the pilot: weather information at points along the route, traffic conditions on the airway and at the terminals, assistance in case of trouble, and in isolated cases almost the sole means of effecting a landing in low fog at the terminal airport. Stations along the federal airways, installed and maintained by the Airways Division of the U.S. Department of Commerce, give weather information collected from 93 weather stations by teletype, while stations of the individual operators handle dispatching, traffic direction, and related matters.

In general, radio methods for course and position determination fall under 3 headings: (1) range beacons, (2) direction finding of aircraft position by ground stations, and (3) direction finding on the aircraft itself.

In the United States the first has been employed almost exclusively. The Department of Commerce has installed 2 types of radio range beacon stations along the federal airways of the country. The aural type making use of code signals indicates, by the interlocking of the "dash-dot" and "dot-dash" into one long dash, that the plane is on the course; periodic station-identifying code letters indicate the course followed. The visual type employing 2 modulation frequencies and a tuned reed indicator shows flight along the course by equal amplitude of reed vibration. Both systems have been described in much detail in various journals.[1,2,3,4,5] The aural range beacons have been in use since the establishment of the airways, while developmental visual stations have now led to the construction of a considerable number of this type. Continual progress is being made in these services, resulting in such improvements as simultaneous telephone and range beacons, T-L antenna system to overcome "night effect," and the reed converter for visual indication.

Directive beacons, with the straight airway between them, are supplemented by small marker beacons at intervals along the route. These low-power transmitters, giving a characteristic signal, serve to indicate position along the airway.

Here, then, is a system of communication, a system of navigation along fixed routes, and means of getting approximate position on the route, which have been of inestimable value.

Full text of a paper (No. 33-53) to be presented at the A.I.E.E. North Eastern District meeting, Schenectady, N. Y., May 10–12, 1933.
1. 2. 3. . . . See bibliography at the end of article.

Navigation along independent routes requires direction and position finding either (1) on the ground with transmission to the aircraft as in use on the airways of Europe or (2) on the aircraft by direction finder or compass. In the former, ground direction-finding stations triangulate on the characteristic radio signal of the plane and, having determined the craft's position by combining their individual readings, transmit it to the plane. This system has the disadvantages that the indications are not continuous and that the position indicated is that occupied by the plane some time previous.

Direction finders based on minimum signal employing loops aboard the craft are in extensive use on marine vessels, lighter-than-air craft, and also to some extent on airplanes. This equipment makes possible the fixing of position by triangulation, and guidance along a route toward or away from a transmitting station by maintaining the indication at the minimum; but it does not show that a deviation is to the right or left of the course. A radio compass makes possible direction finding and gives right and left indication of deviations from the course.

Radio Compass

An ideal radio compass for use in controlling the course of an aircraft would be one that would give right and left indications on both continuous and modulated wave radio signals sensitive around the zero position, and not destroy the characteristics of the signals used in communication.

Radio compasses have been in use for years along the coast to determine the position of ships. In these installations loop antennas are used to get the line between the ground station and the ship, but the loop alone does not tell at which end of the line the ship is located except, of course, that on the east coast the ship naturally will be to the east of the station. In order to determine from which end of the line the signal is coming it is necessary to compare the output of the loop antenna with the output of a vertical wire antenna. This is done by combining the 2 outputs and noting the effect in head phones when the loop is swung from one side of zero to the other.

A radio compass for use on aircraft must give right and left indications on a visual indicator so that if the pilot when flying toward a radio station turns the ship to the right, the indicator must turn to the right; if he is flying on a course away from the radio station and the ship is turned to the right, the indicator must show left, indicating that he is flying away from the radio station. Several radio compasses have been developed to give these indications. In general these contain some form of a synchronized switching device which rapidly switches the polarity of the loop with respect to the vertical antenna and at the same time switches the rectified audio frequency output using a zero-center indicating device; this gives a sense of direction if the loop increases the voltage picked up on the vertical antenna when connected for right indication, and bucks when the indicator is connected for left indication. This principle gives fairly satisfactory results, but it destroys the characteristic of the signal for use in communication and the accuracy is effected by phase-angle shifts in the radio receiver due to any regeneration that might be present.

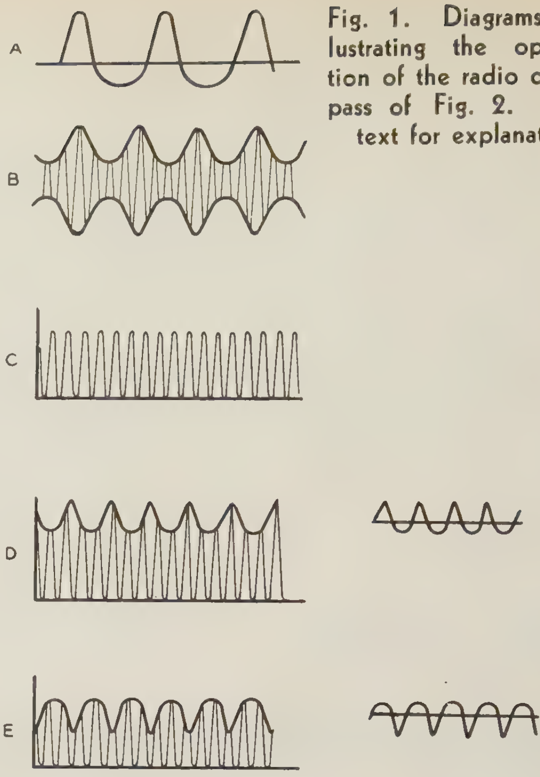

Fig. 1. Diagrams illustrating the operation of the radio compass of Fig. 2. See text for explanation

A radio compass utilizing an entirely different principle has been under development; it does not depend on synchronizing the input and output of the radio receiver, and it does not destroy the modulation that might be present on the radio signal.

A loop antenna has directional characteristics in that the voltage induced in it becomes a minimum when the loop is normal to the direction of the radio wave, whereas a vertical wire antenna has no directional characteristic to waves approaching in a horizontal plane. Also the polarity of the loop with respect to the vertical wire antenna can be reversed by rotation; thus it is possible to use the voltage from the loop to buck or boost the voltage induced in a vertical wire.

The foregoing describes a method of indicating when the loop is not normal to the direction of propagation of the radio wave and also to which side it is turned. The next step is to transform the combined radio frequency energy from the loop and vertical wire to direct current which will reverse when the loop is turned from the bucking to the boosting position. This is accomplished by modulating the output of the loop with an audio frequency having a wave form as shown in Fig. 1*A*. This wave form is maintained through the radio receiver and audio output to a non-linear resistor in series with the visual indicator. A non-linear resistor is one in which the current does not change in proportion to the applied voltage; thus if an alternating current having a wave form as in Fig. 1*A* is applied to the resistor, the polarity of the wave having the highest peak value will cause more current to flow than the opposite

polarity even though the rms values of both sides be the same. This increase in current from one side of the wave causes an indication in the d-c indicator and if the alternating current be reversed the indication will be reversed. Turning the radio loop from its zero position to one side or the other causes the peak side of the audio frequency output of the receiver to appear on one side of the wave or the other.

In Fig. 1*B* is shown the radio frequency envelope of output from the loop, which does not appear except when the loop is turned off normal; this is combined with the steady wave Fig. 1*C* from the vertical antenna. Figure 1*D* shows the resultant when the loop is turned in the proper direction to cause its voltage to add to that in the vertical antenna, and Fig. 1*E* shows the resultant when the 2 voltages are bucking. Figures 1*F* and 1*G* show the resultant a-c rectified currents from the radio receiver detector. When the aircraft is on its course, the radio loop is normal to the radio wave and the voltage across it is a minimum. Therefore there is no effect of the compass attachment transmitted to the receiver and head phones, thus allowing the receiver to be used for communication purposes.

Referring to the schematic diagram, Fig. 2, the compass effect is transmitted through condenser C_4 to the antenna binding post of the receiver, and the audio frequency output is connected directly to the head phones and indicating system. Condenser C_1 and inductor L_1 are used to prevent excessive voice modulation from appearing on the indicator; R is the non-linear resistor and C_2 is a smoothing condenser. The wave shape Fig. 1 is obtained by the action of resistor R, and the grid current in the modulating tube; this wave shape can be duplicated by combining the fundamental and second harmonic in the proper amplitude ratio and phase angle difference. Thus it is possible to modulate the loop energy with an audio frequency f and combine it with a $2f$ frequency at the non-linear resistor; but any shift in phase relation caused by a delayed action in the radio receiver would tend to make the indication insensitive, or if carried too far the indicator would

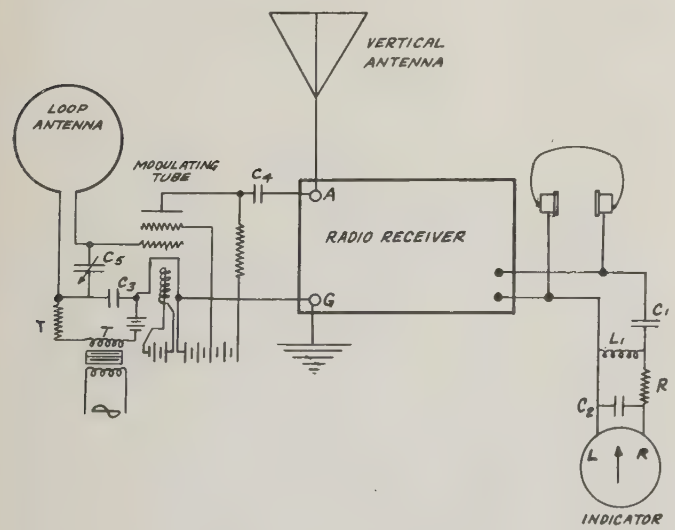

Fig. 2. Schematic diagram of radio compass for air navigation

show reversed directions. This difficulty is a common experience with the type of compass that depends on the synchronized switching between the radio receiver input and output circuits, and prevents the use of any form of regeneration. With the compass just described, regeneration up to the point of oscillation does not interfere with the accuracy of the compass attachment—in fact when the receiver is oscillating as used for continuous wave telegraph reception compass bearings can be obtained, but the sensitivity of the overall system is considerably reduced because of the overload on the detector stage.

Receivers equipped with automatic volume control can be used with this compass because such control not only automatically increases the amplitude of the combined signal from the radio loop and vertical antenna, but also maintains the ratio between the f and $2f$ frequency in the audio output circuit. Referring to Fig. 1 it may be noted that the average values of the radio frequency current when the loop voltage adds to that from the antenna (Fig. 1*D* and *F*) is higher than when it opposes (Fig. 1*E* and *G*). This causes a shift in the operating level at the detector tube and if, when using automatic volume control, an attempt is made to operate on too powerful a signal, erratic results will be obtained. This can be compensated partially by varying the respective pick-up between the loop and antenna. It is experienced only when approaching a powerful transmitting antenna and generally is not required with a hand operated volume control.

The audio frequency required to modulate the loop output can be of any value that will pass through the receiver without too much distortion. There are 2 factors which govern the frequency: if the frequency is higher than 1,500 cycles, a high-pass filter can be used to limit voice effects from appearing on the indicator; because the modulating frequency is made up of a fundamental and second harmonic, the receiver should be capable of handling the second harmonic frequency without too much transmission loss, otherwise the sensitivity will be affected. It also may be desirable to keep the frequency fairly high in order to use the lower range for continuous wave telegraph reception.

The sensitivity around the zero point depends on the type of signal being received. On unmodulated continuous wave stations it is a maximum, and on badly overmodulated waves a minimum, averaging approximately 10 deg for full scale deflection daylight reception on broadcast stations 150 miles away. By using head phones directions can be obtained down to a fraction of a degree.

The distance range of the compass attachment is limited to that of the radio receiver with which it is operated; in general it will give satisfactory bearings on broadcast stations that can be received loud enough for ordinary loud-speaker operation or, in reception on aircraft, the range is about the same as that obtainable for head phone reception. Rough bearings can be obtained in bad static conditions when telephone reception is impractical.

With a satisfactory radio compass it becomes possible to navigate an aircraft with much greater accuracy, with a resultant saving in fuel; it permits

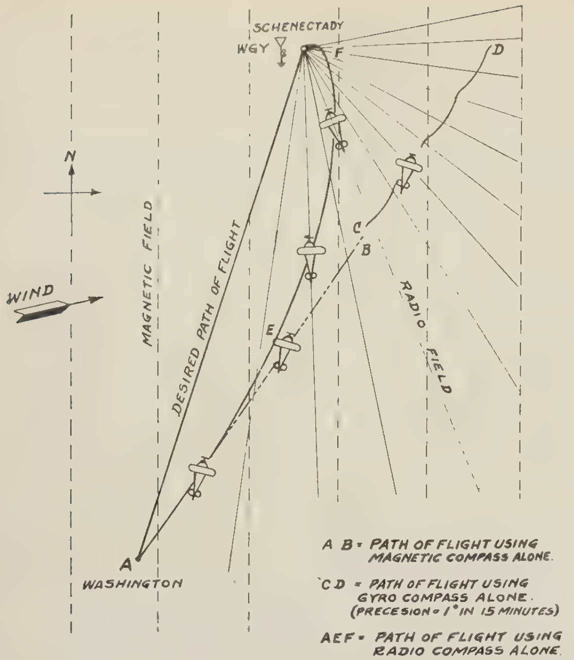

Fig. 3. Diagram showing drift of an airplane from a straight line course, caused by wind

night expeditions over strange territory or water; it is valuable in photographing; when one is lost it becomes useful in obtaining angles for triangulation; and when combined with a magnetic compass it presents a system of navigation which automatically corrects for wind drift.

Combination of Radio Compass and Magnetic Compass

Referring to Fig. 3, if one wishes to fly from Washington, D. C., to Schenectady, N. Y., and maintain his course by following a magnetic compass with a west wind blowing he would travel a course *AB* to the east, never arriving in Schenectady. If he tuned in radio station WGY and flew according to the radio compass the course would be along *AEF* eventually arriving but traveling a considerable distance out of his way. Referring to Fig. 4 it may be noted that angle a between the magnetic north and the course remains constant whereas if the craft should drift to the left, for instance, it might still be headed for its destination by following the radio compass but the angle with respect to the north pole would become b. Thus in order to maintain both the magnetic angle and the radio compass satisfied, it is necessary to keep on a straight line course to the destination.

The following system to accomplish correction for drift will operate with any type of compass, but tests have been made with the magneto compass, hence a brief description of this instrument is given. It is essentially a small d-c generator (Fig. 5) which depends on the earth's magnetic field for excitation and obtains its rotating power either from a 12-volt motor or a wind driven impeller. In order to collect a maximum of magnetic flux for the field, permalloy poles are used. A sensitive center-scale ammeter is used for the indicator and the indication becomes zero when the poles are in the east-west position. The instant the poles are turned away from this position a magnetic field is established across the armature causing a voltage to be generated and an indication on the indicator, the direction depending upon which way the flux travels through the poles.

There is a remote control or course-setter which enables the poles to be rotated to a position which will be east and west when the aircraft is on its proper course. The output of the compass generator also can be used to operate a sensitive polarized relay which in turn can be used to operate an automatic steering engine, Fig. 6. This engine is driven by a 12-volt motor which rotates the steering drum in either direction by the use of electrically operated clutches. The clutches are controlled by the magneto compass and the overall system is stabilized by a follow-up system which introduces a counter emf in the compass circuit eventually becoming equal and opposite in polarity to the current generated by the compass. The follow-up device is operated directly from the steering drum and permits the rudder to be turned an amount proportional to the current from the compass. It also causes the rudder to return to its mid-position without overshooting.

Referring to Fig. 7 it may be noted that in order to maintain a straight course between the starting point and the destination, it is necessary to maintain the radio compass loop L_1 L_2 normal to the course and the magnetic compass poles P_1 P_2 east and west. If the aircraft be permitted to drift to position B and the angles of both compasses are not changed, then it may be seen that the radio loop is no longer normal to the radio station or course; and if the output of the radio compass was used to control the

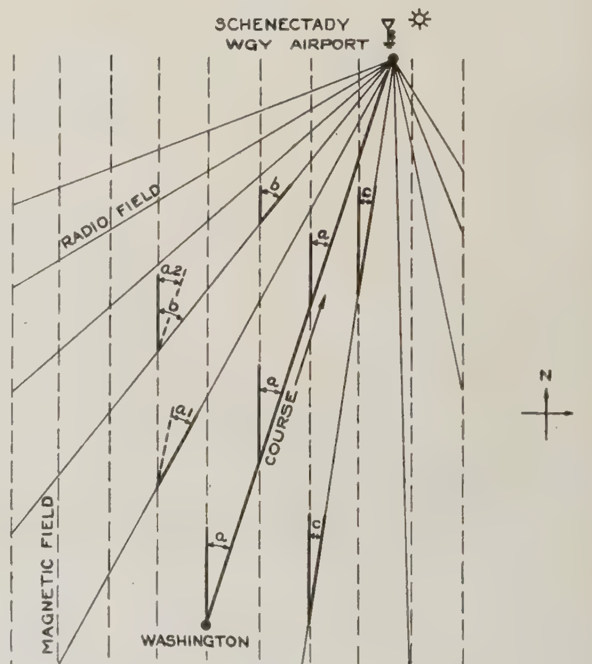

Fig. 4. Diagram showing how an airplane is held to its course by combining radio, magnetic, and Gyro units in a compass system

rudder, the craft would make a left turn toward the straight line course.

In order to make this correction automatic it is necessary to operate the compass pole rotating mechanism with a motor and also to permit the loop to be rotated. Figure 8 shows a test stand equipped with the developmental equipment. The steering engine here differs somewhat from the one previously shown in that it contains an extra set of clutches and a differential gear box, the drum on top of the engine having a small metal rudder which represents the rudder of an aircraft. The control panel is arranged so that the rudder can be operated directly by either the magneto compass, the radio compass, or the combination of the two which gives automatic drift correction. When switched for drift correction the magneto compass poles are automatically kept in an east-west position by using the output of the compass to control the second clutch assembly; this in turn rotates the poles until the compass output is zero. Attached to this clutch mechanism is a differential gear box which is connected mechanically to the rotating mechanism of the radio loop. The differential gear box permits the angle between the radio compass and the magneto compass to be set and after that no matter which way the aircraft is turned the 2 compasses will remain at a fixed angle with respect to the magnetic north pole.

The output of the radio compass controls the rudder and thus the craft is directed according to the angle set up between the 2 compasses. To correct for wind effects the craft will automatically assume a heading or "crab" into the wind a sufficient amount to maintain its course on a straight line. If the wind increases or decreases the "crabbing" angle will automatically change.

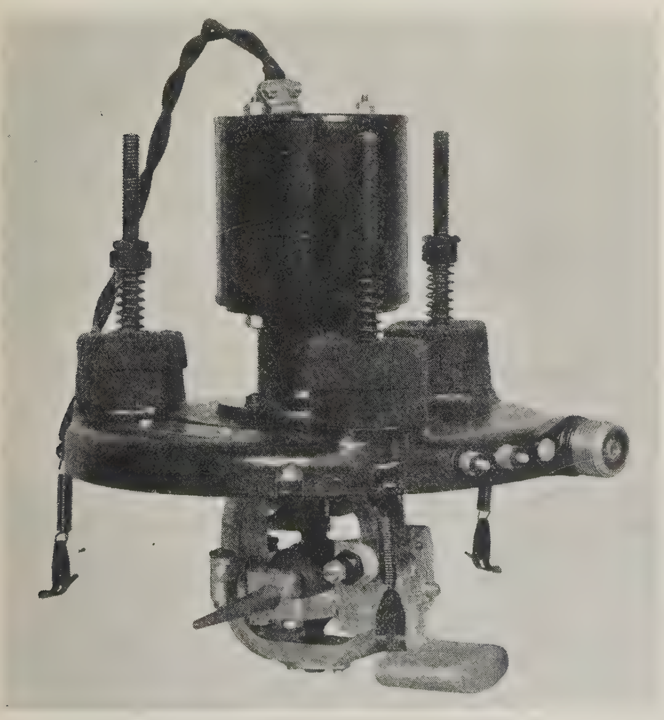

Fig. 5. A motor driven magneto compass generator with cover removed

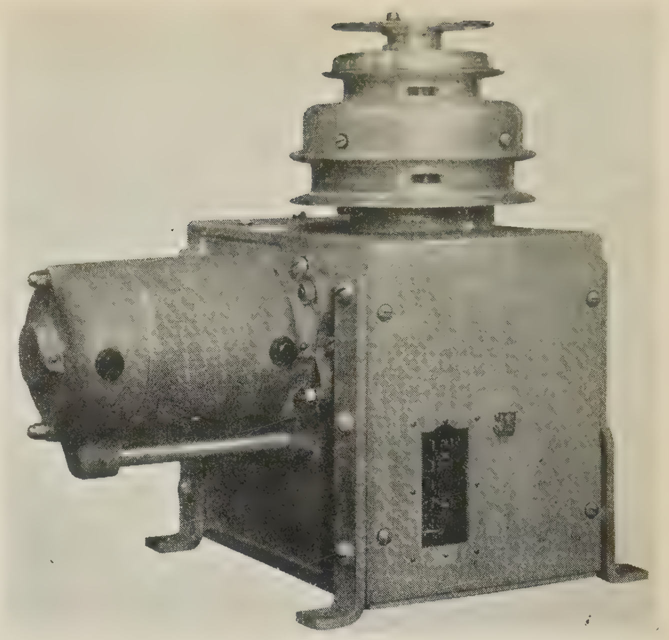

Fig. 6. Developmental aircraft rudder engine for automatic steering, with dynamotor

The gyro turn compensator is used to stabilize the system in rough weather and when making rapid turns, although the equipment is intended for use only for fairly long level flights and not for rapid maneuvers.

Referring to Fig. 8 showing the control panel, the course setter to the right is used to set the angle of the course and the indicator to the left shows the actual heading of the aircraft. By subtracting the 2 angles the difference indicates the angle of crab and is a direct indication of the effect of the wind.

After establishing the ability of maintaining a straight course and the angle of crab, it remains necessary only to determine ground speed to determine the exact location during the flight. This may be determined by orienting the loop on a second radio transmitting station.

Using test equipment a plane has been automatically steered to destination with correction for drift by the described method, but work remains to be done to reduce the equipment to service form.

Landing Aids

The safe landing of aircraft during adverse weather conditions remains the great problem confronting air transportation. In general, transport companies avoid any possibility of being caught in a position where it is necessary to attempt a landing in fog, in the same way that all ocean liners meet their corresponding problem. However, several organizations are now making strenuous efforts to solve this problem. Here it is that all the agencies are to be investigated, radio, sound, light, and any others, for each may contribute to the solution.

The landing of planes at an airport under blind flight conditions requires the guidance of the plane from the beacon course or the course determined by radio compass to an approach course at the airport,

the determination of runway position, knowledge of height above ground and traffic conditions about the port.

Several methods have been proposed and demonstrated, including the Guggenheim Fund work of Major Doolittle, the short-wave radio beam developed by the Aeronautics Research Division of the Department of Commerce at the U.S. Bureau of Standards, the system developed at Wright Field by Captain Hegenberger, and others. As in other flight equipment, it is desirable to limit the total apparatus, particularly that on the plane, to a minimum, and to make use as far as possible of instruments that are needed for normal flights or that become an aid in emergency landings. Thus the relocation of those range beacon transmitters situated near an airport such that one of the radiating courses lies across the airport as now planned by the airways division will assist the pilot, and the use of available receiving equipment aboard the plane without duplication serves to reduce the carried weight to a minimum.

A few portable runway-localizing beacons have been constructed which have outputs of from 10 to 15 watts. These use small cross loop antennas so located that the vertical plane containing the axis of the desired runway bisects the angle between the 2 loops. These beacons are essentially the same as the radio range beacons mentioned previously except smaller in size and output.

The range of the localizer transmitters is from 7 to 15 miles so that a plane may be brought in from a distant range beacon course to the desired runway. It is desirable that the set be adapted to voice modulation, thus placing the operator in telephone communication with the pilot at any time.

The localizing beacon can be used with several types of supplementary aids. Airport boundary marking may be effected by radio or sonic markers each throwing out a barrage through which the plane, in passing, receives an aural or visual indication. The indication of height above ground may be determined by a sensitive barometric altimeter or by a sonic altimeter. The first gives approximate comparative heights which do not follow the contour of the terrain while the sonic altimeter, described elsewhere,[6,7] permits the pilot to know his height during the glide over adjacent ground, the time at which he passes the boundary, providing the sonic type of boundary marker is used, and the gradual approach to the surface of the runway in normal gliding position thus eliminating the necessity for a shock landing. The sonic altimeter likewise is effective in emergency landings.

It is not yet apparent what the ultimate system or systems will be, but whatever leads to successful operation will lean heavily upon radio aids. Tests conducted to date with the equipment described in this article show results indicative of material aid in the solution of problems of flight.

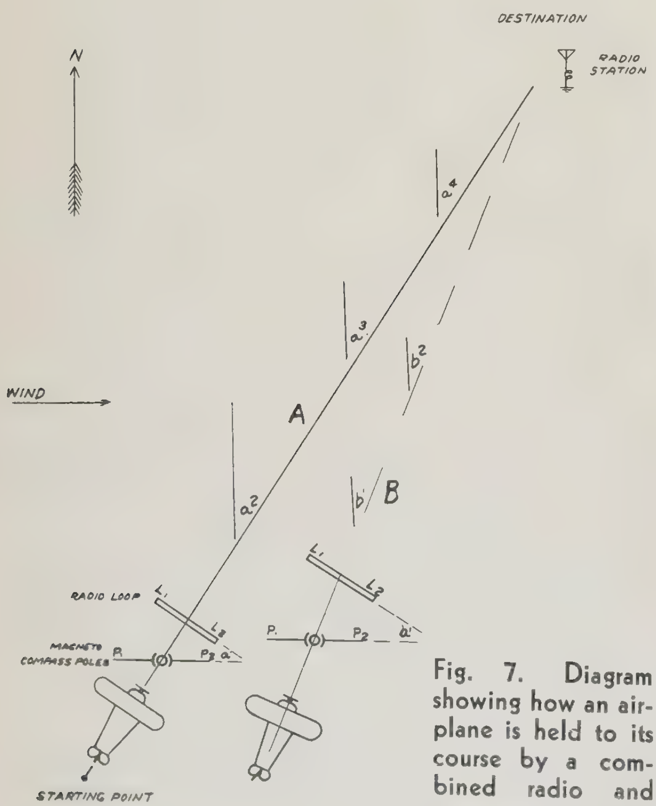

Fig. 7. Diagram showing how an airplane is held to its course by a combined radio and magnetic compass

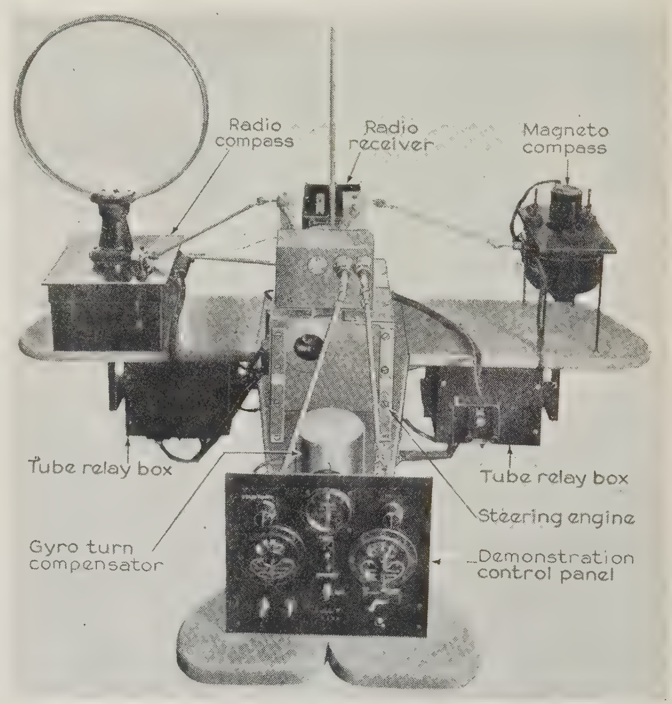

Fig. 8. Experimental automatic steering control with automatic radio drift correction, mounted on a test stand

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The Segregation of Water Power Costs

An analysis of system power costs is of importance to system engineers as well as to the management, provided that the information is in a form readily usable for their particular problems. In the accompanying article is given a useful method of analysis.

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BECAUSE the economic and physical conditions of the territory served by an electric utility as well as the conditions of the utility itself are changing continually, the periodic analysis of the different cost items is necessary to determine the trend of changes in costs. An increase in system load requires new plants and facilities the cost of which varies and in turn varies the cost of power. Distribution costs vary with changes in the character and location of the load; overall costs also will change with wages and cost of fuel or materials. An analysis of system power costs is of importance to the various electric utility engineers, as well as to the management, if the information is in such form as to be readily usable for their particular problems.

Analysis of power costs of a hydroelectric generating station is complicated by the fact that no 2 hydro stations are alike and by the fact that the method of using the station in conjunction with the rest of the system determines how costs may be segregated. The following discussion is divided into 3 parts embracing (1) a brief outline of the method used in segregating system power costs and the development of the fundamental cost items; (2) segregation of power costs of hydroelectric stations into their component parts; and (3) peculiarities of hydro power and an outline of a method of determining an average cost of power for a hydro unit or hydro system.

Essentially full text of "Segregation of Hydroelectric Power Costs" (No. 32-112) presented at the A.I.E.E. Pacific Coast Convention, Vancouver, B. C., Aug. 30–Sept. 2, 1932.

I—Outline of System Power Cost Analysis

The analysis of system power costs consists of: (1) dividing the system into its component parts and determining the yearly expenses of each part; and (2) prorating the different yearly expenses for each division between demand costs, energy costs, customer costs, and any other special costs that may be of interest. The main divisions applicable to the usual system are: production, transmission, distribution, customer costs, and general costs. In addition to the foregoing any special costs that do not apply to the system in general, such as street lighting costs where the utility maintains the lighting system, street railway costs where operation and maintenance is by the utility, and electric appliance sales costs that should be kept separate.

Annual production costs can be prorated between different generating plants; transmission, distribution, and customer costs each can be divided into geographic divisions; and general costs prorated between production, transmission, and distribution. With these divisions, the cost of power at any particular point on the system can be obtained.

The segregation of annual costs between demand, energy, and customer costs is the basis for the so-called 3-part rate structure which has been in existence for many years. Although the usual rate structure does not include customer costs as a special item, this item is recognized as one of the costs of power and is included with the demand costs. Demand costs are those which are proportional to the power or kilowatts, but are independent of the amount of energy used, whereas energy costs are those which vary with the energy used and are proportional to kilowatt hours. Customer costs are those chargeable to each customer independent of the amount of power or energy, and which are approximately the same for each customer.

The segregation of production, transmission, and distribution into demand costs and energy costs requires a careful analysis of how the equipment is to be used and how the costs are incurred. On steam generating plants the annual fixed costs are assumed to be demand costs and the variable costs are energy costs. Distribution and transmission annual costs usually are considered to be demand costs.

In ascertaining the cost of power on most systems the utility can be considered a "going concern" with a built up load that usually is growing. It is advisable to keep at all times a reserve capacity, both in kilowatts for peak demand and in kilowatthours, the amount of which is a matter of judgment determined from experience and is different on every system.

II—Analysis of Hydroelectric Power Costs

The following discussion of the 4 main types of generating plants should not be construed as covering the subject completely. Many plants are built for special purposes and all such plants would require special analysis in the light of their intended use, but in accordance with the general principles laid down for the main types of plant.

In the cases of associated transmission lines, their annual costs can be analyzed similarly to, and should be included with, those of the hydro station.

Annual costs on the average hydroelectric plant are practically all fixed costs, about the same whether the plant turns out 5 or 100 per cent of the available energy. Since supervision of a plant is required whether the turbines are operating or not, operating and maintenance expenses are essentially the same regardless of plant load factor.

The large items of annual expenses are interest, depreciation, taxes, and insurance on the large investment required. On first thought this would lead to the conclusion that all hydro costs are in the nature of demand costs, but that is true only for certain hydro stations.

The energy output of a hydro station is limited to some potential value determined by stream flow. Use of the entire potential output may be impossible because periods of high stream flow may not coincide with periods of high system demand, or the installed generating capacity may limit the output. Most hydro stations have some pondage or storage which makes them more valuable to the system in that more potential energy in the stream becomes available to meet system load requirements. Construction costs for a given hydro project will vary with the amount of generating capacity to be installed, but this variation is usually small in comparison to the total cost of the project. As an example, assume a hydro project having a fixed stream flow with pondage available to store the entire flow for 12 hr. Under these conditions the same total energy can be turned out in 12 hr as is possible in 24 hr, if the generating capacity of the plant is at least double the capacity required for continuous 24-hr service. To increase the maximum kilowatts above that required for a 24-hr duty the plant requires additional capacity in turbines, generators, transformers, circuit breakers, buses, water conduits, power house, and surge tanks. The cost of the dam, reservoir, water rights, and lands are approximately fixed and in most cases represent the bulk of the cost of the project. It follows then that as the plant factor goes down, the cost per kilowatt of the project also goes down and the total annual costs are increased only the amount necessary for the added depreciation, taxes, insurance, and interest.

The original cost of a project can be divided into 3 classifications:

1. Costs approximately proportional to generating capacity, such as for turbines, generators, penstock, and transformers.
2. Costs independent of generating capacity, such as for lands, water rights, dam, reservoir, construction plant, station service equipment, and control equipment.
3. Costs which would apply to both groups, such as for water conduits, surge tank, power house, buses, and switching equipment.

Proration of the third group between the first 2 groups in accordance with the estimated expenditures that would apply to each group is necessary, leaving the 2 groups of proportional and independent costs. For the purpose of this discussion the annual costs that do not vary with changes in kilowatt plant rating are called "base" costs, and the costs approximately proportional to the kilowatts are called "proportional" costs. The distinction between proportional *first* costs and proportional *annual* costs must be kept in mind. The first costs, which can be divided between proportional and base first costs do not vary directly with the proportional and base yearly costs because the yearly expense of operation and maintenance is considered to be part of the base yearly costs. The balance of the base yearly costs is made up of interest, depreciation, insurance, and taxes on the investment required for the base first costs.

Hydroelectric power stations are designed to exercise a particular function in carrying system load, as determined by stream flow characteristics, useful storage at the hydro site, and the type of system load. Hydro stations can be divided into the following 4 general classes, and for illustration an example of each class is given.

1. Complete development with complete storage; stations designed to utilize the entire stream flow energy during years of mean or minimum stream flow by means of storage. Chelan and Cushman plants.

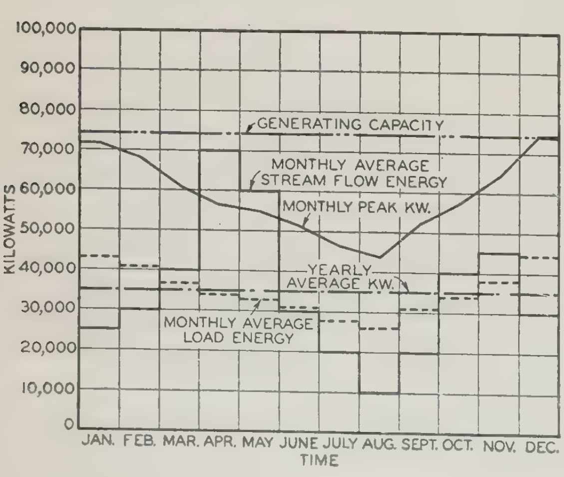
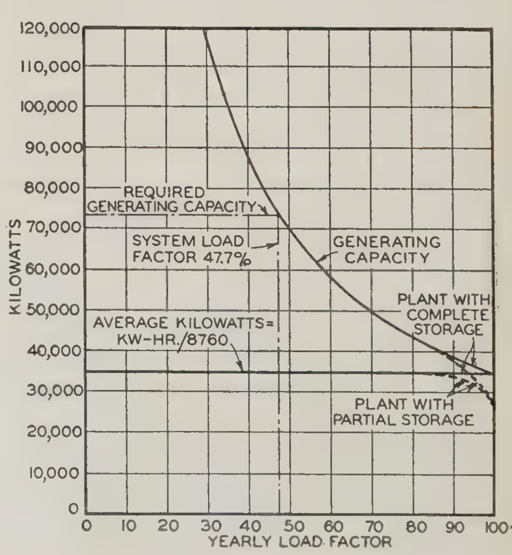


Fig. 1. (Left) Yearly operation by monthly averages of a complete hydro development having complete storage

Fig. 2. (Right) Effect of load factor upon energy output and generating capacity of a complete hydro development having storage



2. Complete development with partial storage; stations having pondage available for taking care of the daily load variations, but not enough to store all the seasonal variation of stream flow for use when needed during the dry period of the year. Baker River and Long Lake plants.

3. Partial development; stations capable of carrying full load at machine rating continuously. Nisqually and Niagara Falls plants.

the monthly load factor is assumed to be 60 per cent for every month, hence, with the monthly variation in load as shown, the yearly load factor would be 47.7 per cent. It is the hourly variation in load throughout the day, not the seasonal variation, that has the large effect in determining the yearly load

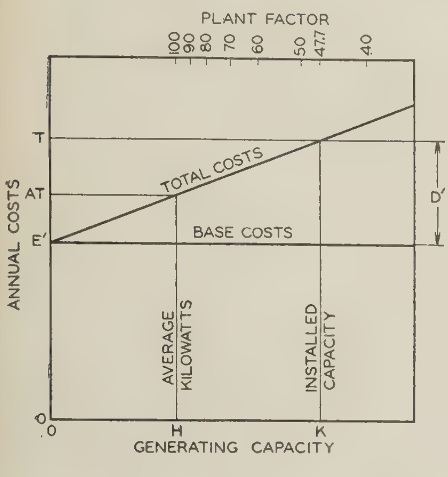
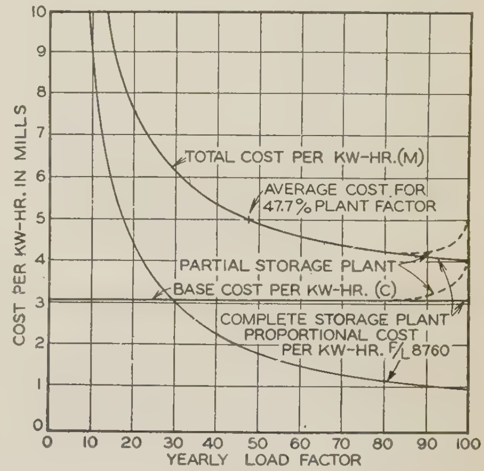


Fig. 3. (Left) Effect of variations in generation capacity upon annual costs of operating a hydro station

T = total annual costs as constructed
D′ = annual proportional costs as constructed
E′ = annual base costs
A = fraction of total annual costs as constructed necessary to run plant designed for 100 per cent load factor
K = peak kilowatt capacity
H = average kilowatts = kwhr output/8,760

Fig. 4. (Right) Power costs for complete hydro development having storage



4. Complete development without storage or pondage; stations utilizing as much of the stream flow as is economically possible without storage or pondage but with the help of auxiliary power. By complete development is meant utilizing as much of the potential energy of the stream as is possible with the economical storage and type of load that is available. Rock Island plant.

Complete Development With Complete Storage

This type of project is designed to utilize at any required load factor the entire potential energy of the stream during years of mean or minimum flow, with sufficient storage capacity to avoid wasting water. Whether to use in the analysis the mean, minimum, or some in-between stream flow is determined by the amount of steam standby on the system that can be used exclusively by that plant in case of water shortage. In the case of storage adequate to meet several low water years, the maximum stream flow which would be available continuously, as determined by the mass diagram or stream flow hydrographs, is used, augmented by the steam standby. In any case the annual cost of the steam standby must be charged against the hydro project.

As an illustration of this type of development, Fig. 1 shows by monthly averages the yearly operation of a hydro station. The necessary reserve capacity is not included in the following discussion of this assumed project.

The average yearly output of 35,000 kw is assumed to be backed by enough standby energy to supply the difference between the low water years and the average energy available as determined by the stream flow records: There is assumed to be sufficient storage in the basin above the dam to store the excess energy that occurs during the months of March, April, May, October, and November to be used during the balance of the year so that all the energy in the stream is available to meet the load as determined by the monthly load curve. The amount of generating capacity necessary to meet the yearly peak is determined by the yearly load factor. In Fig. 1

factor on the usual system. The variation of installed generating capacity with load factor is expressed by

$$L = \frac{H}{K}$$

The following notation is used throughout this discussion:

A —fraction of total annual costs of plant as built that would be necessary to run plant had it been designed for 100 per cent load factor.
C —energy cost per kilowatthour.
C'—base cost per kilowatthour.
D —annual demand costs.
D'—annual proportional costs.
E —annual energy costs.
E'—annual base costs.
F —annual demand cost per kilowatt.
F'—annual proportional cost per kilowatt.
H—average kilowatts (kilowatthours/8,760).
K—peak kilowatts or kilowatts of generating capacity.
L—yearly load factor.
M—total cost per kilowatthour.
P—plant factor.
T—total annual costs.

On this type of development the energy available in the stream H is constant, hence the required generating capacity is inversely proportional to the load factor. This relation is shown in Fig. 2 for the hydro station of the foregoing illustration. Energy is constant at 35,000 average kilowatts regardless of load factor, whereas the required generating capacity for a load factor of 47.7 per cent is 74,000 kw. If the load for the station had a load factor of 100 per cent it would be necessary to have installed only 35,000 kw.

The relation between generating capacity and annual station costs is shown in Fig. 3. The total annual costs T are made up of the base costs E' and the proportional costs D'; base costs E' are constant regardless of the generating capacity whereas the proportional costs D' vary directly with the generating capacity. Because the energy output is constant and the generating capacity varies inversely

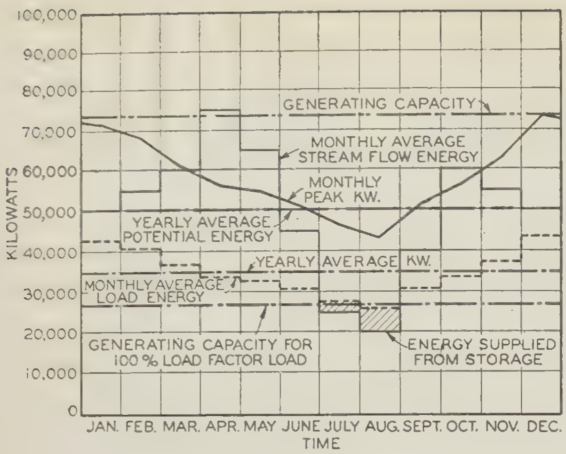
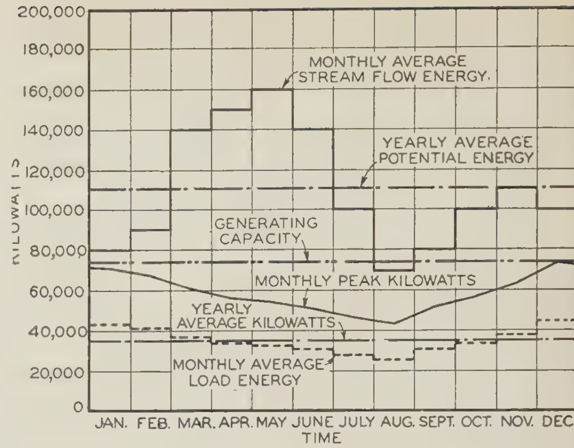


Fig. 5. (Left) Yearly operation by monthly averages of a complete hydro development having partial storage

Fig. 6. (Right) Yearly operation by monthly averages of a partial hydro development



with the load factor, the total cost per kilowatthour can be expressed by

$$M = \frac{E'}{H\,8760} + \frac{D'}{KL\,8760} \qquad M = C' + \frac{F'}{L\,8760}$$

There are 2 methods of segregating the base and proportional annual costs on an actual project of this type: (1) divide the actual construction cost between base and proportional and from these determine the base and proportional annual costs; (2) obtain, by means of an estimate of what the annual cost of operating the plant would have been had it been designed for a 100 per cent load factor, the slope of the total annual cost line (Fig. 3) which is the annual proportional cost per kilowatt F'.

$$F' = \frac{(T - AT)}{(K - H)} = \frac{T(1 - A)}{(1 - P)K}$$

The base cost per kilowatt hour is

$$C' = \frac{T(A - P)}{H\,8760\,(1 - P)}$$

That the proportional cost per kilowatt F' is the demand cost of service and that the base cost per kilowatt hour C' is the energy cost of service is evident from the foregoing. Likewise the annual proportional costs D' are annual demand costs and the annual base costs E' are annual energy costs.

In Fig. 4 is shown the cost per kilowatthour for different load factors as calculated for the power station referred to in Fig. 1. The base or energy cost of service is constant, but the proportional or demand cost of service varies inversely with the load factor.

Complete Development With Partial Storage

Most hydroelectric developments do not have storage adequate to meet the system load without wasting water during the mean or minimum stream flow year, and so would come in the classification of partial storage. For the purpose of this discussion all plants that have pondage enough to take care of the maximum daily peak from daily stream flow, but not enough for complete storage, are considered to be partial storage plants.

In the example of this type of development, as shown in Fig. 5 storage is assumed adequate to meet the variation in daily load as well as to raise the station output a small amount during the low water months of the summer. The same load curve is assumed as was shown for the complete storage development of Fig. 1. The yearly average potential stream flow energy is 50,000 average kilowatts and the difference between the usable and the potential is 15,000 average kilowatts which is wasted.

Because of restricted storage the generating capacity of the plant, if designed for 100 per cent load factor, would be 27,000 kw instead of 35,000 kw and the energy output also would be cut down. As the generating capacity of the plant is increased from 27,000 to 44,000 kw the usable energy output is increased from 27,000 to 35,000 average kilowatts and the yearly load factor reaches approximately 80 per cent which is due to the variation in seasonal load, not the variation in the daily load. To take care of the hourly load variation there must be installed additional generating capacity which does not increase the energy output. To increase the energy output above 35,000 average kilowatts without the use of auxiliary power, obviously would require an increase in load in the nature of secondary power during the period of the year when there is an excess of stream flow. Variation of energy output and generating capacity is as shown in Fig. 2, and for load factors from 0 to 80 per cent is the same for this assumed development as for the one shown in Fig. 1. For load factors between 80 and 100 per cent the energy available and the generating capacity are less, because of the restriction imposed by the type of site.

The same power cost equations, with correction factors, would apply to this type of development as to the development with complete storage. The proportional cost per kilowatt in the case of partial storage developments may be obtained by the second method as outlined for complete storage developments. In this case an estimate of annual expenses is made for operating the plant with generating capacity corresponding to the annual average load as if it were 100 per cent load factor, and the correction factors applied to take care of the decrease in kilowatthours.

The curves showing cost per kilowatthour for the partial storage plant (Fig. 4) are the same as for the complete storage plant so long as the energy output is the same. The base cost per kilowatthour at any given load factor above 80 per cent is increased by the ratio of the average yearly load divided by the

average usable energy. This in turn increases the total cost per kilowatt hour at those load factors.

Partial Development

Under most circumstances the hydro plant is designed to utilize as much of the available energy of the stream as is economically possible, hence there are few finished projects that would come within the partial development classification. The Niagara Falls power stations are outstanding examples of this type of development because the amount of water available for power purposes is fixed by international treaty at a certain percentage of the minimum flow of the Niagara River. Uncompleted plants designed for ultimate complete development of a river sometimes would come under this classification. The characteristic of this type of development is that the plant is capable of furnishing at 100 per cent load factor power equal to its installed capacity.

Conditions of stream flow and load for a development of this class are shown in Fig. 6. Load and generating capacity the same as assumed in the 2 classes of development previously discussed are shown.

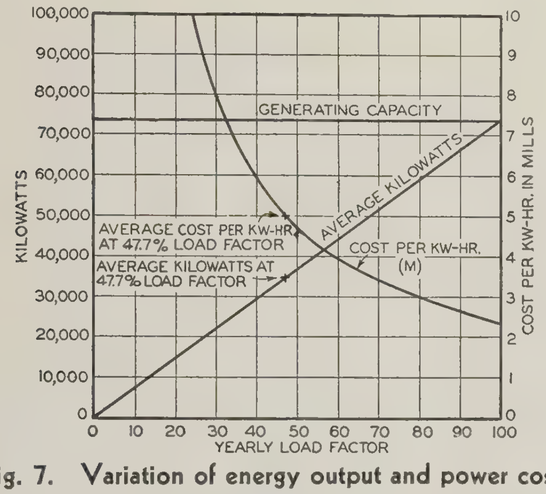


Fig. 7. Variation of energy output and power cost for a hydro development having a fixed generating capacity

There are 2 ways of looking at this type of project: (1) the amount of water than can be taken from the stream is fixed, or (2) the installed generating capacity is fixed. If the amount of water that can be taken from the stream is fixed, the plant output is fixed and the cost analysis would be the same as for a plant having complete storage. Some plants designed many years ago with a minimum of generating capacity could not have additional generating units added now without rebuilding the entire plant, and until that is done they can be called fixed capacity plants.

With a plant of fixed generating capacity the kilowatthour output is proportional to the load factor (Fig. 7), the year cost of operating the project is fixed, and the cost per kilowatthour becomes

$$M = \frac{T}{KL\ 8760}$$

The cost per kilowatt (T/K) is the demand cost of service, so that for this type of project all station costs are considered to be demand costs.

Complete Development Without Pondage

A hydro project without storage or pondage usually cannot be used economically without other means of supplying the system load demands during periods of low stream flow, for stream flow fluctuations never follow the load demand of a system supplying the usual type of loads. If the stream is flashy the plant cannot be relied upon to furnish the power when required, so that its development would be used to supply energy only. As long as the energy can be used on the system the cost per kilowatthour would be the same regardless of load factor

$$M = \frac{T}{\text{Kwhr}} = \frac{T}{H\ 8760}$$

and in this case all station costs are energy costs of service. The demand cost of service is determined from the cost of the necessary auxiliary power.

Value of the average kilowatts H is determined from the duration curve of the stream. A duration curve for this type of development is shown in Fig. 8 which shows also the average kilowatts or kilowatthours available in the stream with different installed generating capacities as calculated from the duration curve.

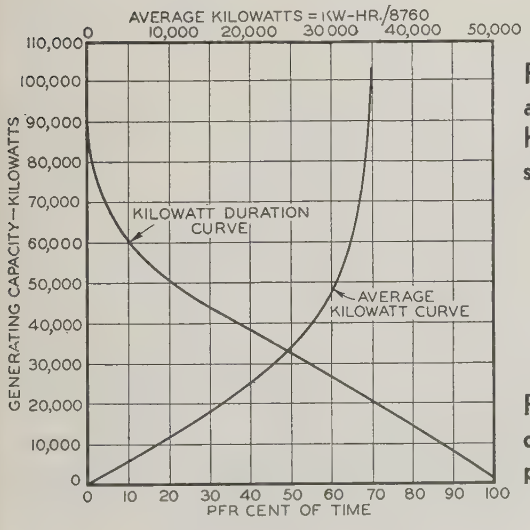


Fig. 8. (Left) Duration and energy curves for a hydro plant having no storage or pondage

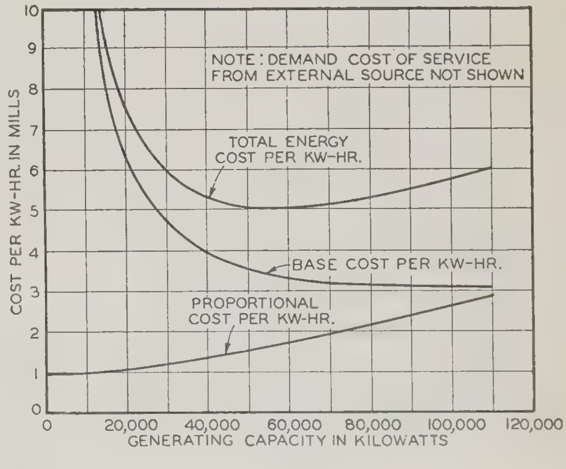


Fig. 9. (Right) Energy cost of power for a hydro plant having no storage or pondage

Annual costs per kilowatthour for the development with different values of installed capacities are shown in Fig. 9. The most economical development would be 60,000 kw provided that the night load on the system is great enough to use the entire power from this station. If in order to use the energy from this type of station it were necessary to provide additional demand capacity by steam or by more units in other stations the cost of the additional demand capacity would have to be included with these station costs in determining the economical development.

III—Average Cost of Hydroelectric Power

So far the discussion has to do with the segregation of hydroelectric power cost into the 2 components of demand and energy costs for plants delivering energy up to their capacity. This condition is not realized often in practice, but the relation between the demand and energy costs, as determined in the foregoing, is fixed within limits regardless of the loading on the plant.

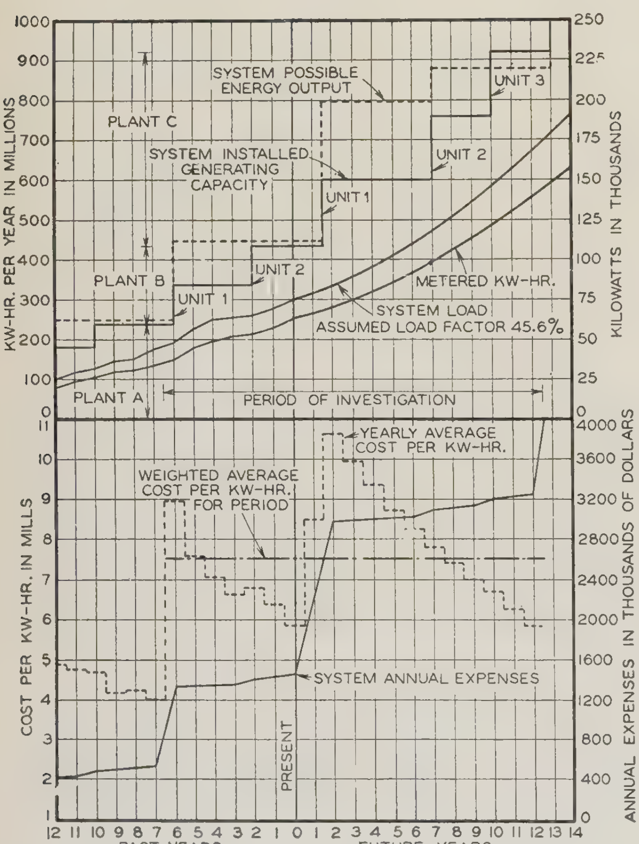


Fig. 10. Load, capacity, expenses, and power cost for a hydroelectric system over a period of years

The usual hydro system that has a growing load cannot construct new hydro plants in such a way that the system annual expenses increase proportionately as the load increases. As a new plant is added, requiring a large outlay for base costs, the yearly expenses increase by a large proportion while the yearly growth in load may be only normal, or less. Before the plant is loaded there is likely to be a period of many years in which the annual expenses are practically constant, but as the load increases the cost of power decreases. The length of time to be used in arriving at the average cost of power is determined by the use for which the investigation is made. The annual cost each year is important for operating, but for rate analysis an average cost over a period of years is essential. The immediate past experience of the utility and the future expected conditions as to load growth and the expansion program are essential in determining the average power cost over a period of years, to be used for rate investigation. The number of years to be used in determining this average cost is important because it affects the cost materially. Past experience should be included back as far as a point in the life of the system where the accumulated revenue is equal to the accumulated expenses. How far into the future the period of investigation should extend is determined by the length of time the forecasts of construction program and load growth can be made and still be within the desired accuracy of the investigation.

As an illustration of the relation between construction program, load growth, and average cost of power, the yearly statistics of an assumed system are shown on Fig. 10. The upper diagram shows the growth in load that has occurred in the last 12 years and the expected growth during the next 14 years. The rate of growth has been approximately 7 per cent in the past and is expected to continue at the same rate in the future. The present load is being carried by the 2 hydro stations, A and B. The proposed hydro development plant C is expected to take care of the system growth for the next 13 years and the proposed construction program, is as shown on the upper diagram.

The system annual expenses are shown on the lower diagram. It is assumed that the accumulated expenses were equal to the accumulated revenue at the time plant B was constructed 6 years ago. The average cost of power for the period of investigation, which extends into the future through the known construction program, is weighted to take into consideration the varying yearly average cost per kilowatt hour and the increase in load. If the revenue is based upon the average cost of power over the period of investigation it is evident that the yearly revenue is insufficient at times to meet the yearly expenses. The utility would have to borrow money to take care of such a condition, so that interest would have to be charged under certain conditions for the use of the borrowed money.

By such an analysis of the past and future conditions of the utility some point in the period of investigation can be found that will have a system load and system expenses that will give an average cost of power for the period.

Principal uses of the analysis are in the economic selection of methods of meeting the demands of load growth and in the location of hydro plants when there are several sites from which to choose. The analysis also is useful in determining the economic combination of steam and hydro generating capacity.

Power, Power Factor, and Reactive Volt-Amperes

As part of the symposium on reactive power to be conducted at the Institute's Schenectady, N. Y., meeting, May 10–12, 1933, the following article discusses the relations between power, reactive volt-amperes, and power factor for sinusoidal and non-sinusoidal electromotive forces and currents. Vector equations for these relations are derived, and polyphase power and reactive volt-amperes are defined. Non-linear circuits are discussed. The method of symmetrical components is used for the analysis.

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THE current ideas regarding the relations between power, reactive volt-amperes, volt-amperes, and power factor were the outcome of an attempt to express the theory of electric circuits subjected to non-sinusoidal electromotive forces in terms of an equivalent sine wave. The equivalent sine wave of a non-sinusoidal wave is a sine wave having the same mean square value as the non-sinusoidal wave. In the elementary theory of electric circuits it was assumed that non-sinusoidal electromotive forces impressed on a linear electric system could be replaced by their equivalent sine waves without causing substantial error in the result, which implied that the wave form of the currents set up in the system was the same as that of the impressed electromotive forces. Later on engineers came to realize that this specification for non-sinusoidal waves was inadequate and another factor was introduced, namely, form factor which was defined as the ratio of maximum value of the actual wave to that of the equivalent sine wave. This factor did not help to any extent in defining the relations between volt-amperes, reactive volt-amperes, and power for non-sinusoidal waves, for the simple reason that these quantities are not definable by means of 2 factors.

Elementary Theory of Energy Flow Relations in Linear Electric Circuits

A linear circuit, however complex, is defined as one in which an applied sinusoidal electromotive force will produce only sinusoidal currents. The characteristic of such a system or net is defined by the principle of superposition which for the present purpose may be stated as follows: If the connections of a linear net *remain unchanged* during the introduction of any electromotive forces in the net either simultaneously or in any sequence whatever, the resulting currents are the same as if each electromotive force were applied to the network at rest individually at the proper instant and the resulting currents superposed. Thus each electromotive force acts upon the system as if it were independent of all the others. The fact that the system must remain unchanged during the introduction of these electromotive forces has been emphasized for the reason that it is not always realized that the closing of a pair of terminals through a generator changes a network and, therefore, the principle of superposition no longer holds. In the case we are considering, however, it is supposed that certain electromotive forces are already established and they may be considered as having been introduced simultaneously or separately without any change in the network. Commercial systems are never strictly linear, on account of the presence of iron in the circuits of electric machines, but the effect of such non-linear elements in the system in general may be ignored. There are cases, however, where they become of importance, such as, for example, cases of telephone interference. In such cases each harmonic must be considered independently with reference to its source.

If we consider a linear system in which all the elements consist of resistance and self-inductance with a sinusoidal electromotive force impressed, the relations between volt-amperes, power, and reactive volt-amperes are expressed as follows where E and I are the root mean square values of electromotive force and current:

$$\left.\begin{aligned}\text{Electromotive force} &= E\cos\omega t\\ \text{Current} &= I\cos(\omega t-\alpha)\\ \text{Volt-amperes} &= EI\\ \text{Power} &= EI\cos\alpha\\ \text{Reactive Volt-amperes} &= EI\sin\alpha\end{aligned}\right\}\qquad(1)$$

We may represent the electromotive force E cos ωt by two equal vectors of length equal to $^1/_2$ the mean square value, one rotating positively the other negatively, denoting the positively rotating vector by $\breve{E}$ and the negatively rotating vector by $\hat{E}$

$$\begin{aligned}e &= \sqrt{2}\,E\cos\omega t = \frac{\breve{E}+\hat{E}}{\sqrt{2}} = \frac{Ee^{j\omega t}+Ee^{-j\omega t}}{\sqrt{2}}\\ i &= \sqrt{2}\,I\cos(\omega t-\alpha) = \frac{\breve{I}+\hat{I}}{\sqrt{2}} = \frac{Ie^{(j\omega t-\alpha)}+Ie^{-(j\omega t-\alpha)}}{\sqrt{2}}\\ ei &= \frac{\breve{E}\hat{I}+\hat{E}\breve{I}}{2}+\frac{\breve{E}\breve{I}+\hat{E}\hat{I}}{2}\end{aligned}\qquad(2)$$

In the vector representation of electromotive forces and currents the convention is to use the positively rotating vectors E and I. It will be observed that $\breve{E}$ and $\breve{I}$ enter into the expression for ei symmetrically and therefore with equal authority. On the other hand in practical problems $\breve{E}$ is the known function of the independent variable t while $\breve{I}$ is the dependent function, it would therefore seem consistent to define energy flow into the circuit by

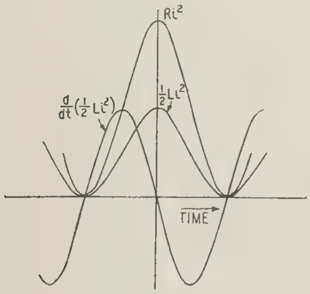
$$P + jQ = \breve{E}\hat{I} \qquad (3)$$

Full text of a paper (No. 33-59) to be presented at the A.I.E.E. North Eastern District meeting, Schnectady, N. Y., May 10–12, 1933.

This convention is seen also to be consistent with the d-c analogy; namely, since the impedance Z in an a-c system takes the place of resistance R in a d-c system then

$$\begin{array}{ll} \text{Direct current} & \left\{\begin{array}{lll} E & = RI & \\ \text{Power} & = EI & = RI^2 \end{array}\right. \\ \text{Alternating current} & \left\{\begin{array}{lll} \check{E} & = Z\check{I} & \\ P + jQ & = \check{E}\hat{I} & = ZI^2 \end{array}\right. \end{array} \quad (3)$$

The above arguments, logical as they appear to the writer, may not be convincing to some. For such it will be necessary to deduce the equation of flow of energy into a circuit from the equation of



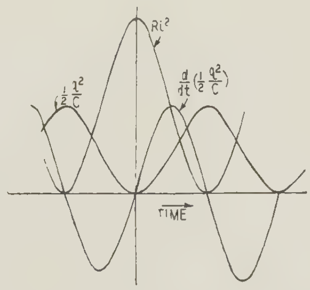


Fig. 1. (Left) Flow of energy relations as expressed by eq 4 for resistance and inductance in series

Fig. 2. (Right) Flow of energy relations as expressed by eq 6 for resistance and capacity in series

energy. In a circuit having resistance and inductance in series the rate of dissipation of energy or power is

Dissipation $= Ri^2$
The kinetic energy is

$$T = \frac{1}{2} Li^2$$

Therefore, the flow of energy is

$$Ri^2 + \frac{d}{dt}\left(\frac{1}{2} Li^2\right) \quad \text{or} \quad (4)$$

$$\left(Ri + L\frac{di}{dt}\right) i \quad (5)$$

Now a little consideration will convince any one familiar with dynamical systems that the instant at which the kinetic energy reaches a maximum must coincide with the instant of maximum dissipation of energy through friction, and the epoch of maximum rate of storage must necessarily take place prior to that of maximum storage and therefore prior to that of maximum rate of dissipation. In a non-conservative system constrained to move under a sinusoidal force the cycle of stored energy in the system coincides in phase with the cycle of energy rate of dissipation; the total kinetic energy is always positive. The rate at which energy is stored into the system or the work done by the force in producing motion against the inertia of the system is $\frac{d}{dt}\left(\frac{1}{2}Li^2\right)$. The maximum inflow of stored energy therefore occurs when the stored energy is $^1/_2$ its maximum and increasing, and therefore when the rate of dissipation is $^1/_2$ its maximum value and increasing, and the maximum outflow of stored energy occurs at the same point of the stored energy cycle when it is decreasing, that is at the same point of the decreasing dissipation cycle. The cycle of inflow of stored energy is therefore in *phase advance* of the cycle of dissipation or power inflow by a right angle.

These cyclic flow of energy relations are shown in Fig. 1, as expressed by eq 4 and in Fig. 3 for those who are happier when dealing with electromotive forces and currents these relations are shown as expressed by eq 5.

For a circuit having potential energy, the stored energy is

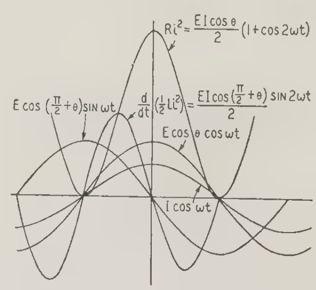
$$W = \frac{1}{2}\frac{q^2}{C}$$

where q is the change at any instant and C is the capacity. The inflow of energy into the system is given by

$$Ri^2 + \frac{d}{dt}\left(\frac{1}{2}\frac{q^2}{C}\right) \quad \text{or} \quad (6)$$

$$\left(Ri^2 + \frac{q}{C}\right) i \quad (7)$$

In the dynamical analogy q is the coordinate of the motion, i is the velocity. Starting with maximum velocity at time zero, the spring (supposed to be linear) will have reached $^1/_2$ its maximum deflection and the maximum stored energy will occur when the velocity becomes zero, that is, when Ri^2 is zero. Thus the cycle of energy storage is of exactly the same form as that of the rate of dissipation of energy but lagging 180 deg. Therefore, the cycle of inflow of potential energy $\frac{d}{dt}\left(\frac{1}{2}\frac{q^2}{C}\right)$ will lead the energy storage cycle by 90 deg and will lag the rate of energy dissipation cycle by 90 deg. In Fig. 2 is shown this expressed in terms of the dissipation and stored energy cycle as given by eq 6, and in Fig. 4



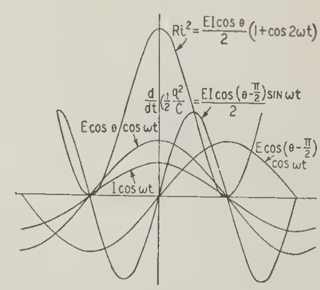


Fig. 3. (Left) Flow of energy relations as expressed by eq 5 for resistance and inductance in series

Fig. 4. (Right) Flow of energy relations as expressed by eq 7 for resistance and capacity in series

in terms of current and electromotive forces as in eq 7.

In dealing with cyclic quantities such as alternating currents and electromotive forces the convention has been standardized of representing such quantities by positively rotating vectors in the complex plane, the projection of these vectors on

the real axis giving the instantaneous value or, where $\check{E}$ and $\check{I}$ are root mean square, the instantaneous values divided by $\sqrt{2}$. The only difference between energy flow values and currents and electromotive forces is that the axis of rotation of the former is displaced from the origin by the amount $P + jQ = \check{E}\hat{I}$ which gives the mean power or rate of dissipation as the abscissa and the value of the rate of energy storage which is a purely sinusoidal quantity as ordinate. The rotating vector is the quantity $\check{E}\hat{I}\ e^{j2\omega t}$ rotating about the displaced axis of rotation which since at $t = 0$, $\check{I}$ and $\hat{I}$ are both wholly real gives $\check{E}\hat{I}\ e^{j2\omega t} = \check{E}\check{I}$.

The instantaneous power vector diagram therefore is properly expressed by

$$ei = \left.\begin{array}{l}\text{real part of } \check{E}\hat{I} + \check{E}\check{I}, \quad \text{or} \\ \check{E}\hat{I}(1 + e^{j2\omega t}), \quad \text{or} \\ (P + jQ)(1 + e^{j2\omega t})\end{array}\right\} \tag{8}$$

If it is desired to obtain the diagram in terms of the cyclic components of P and jQ we should leave jQ out in the last equation, since it is stationary and its projection on the real axis is zero. This gives the expression:

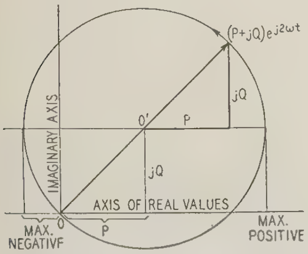
$$ei = P(1 + e^{j2\omega t}) + jQe^{2\omega t} \tag{9}$$

where P is the real part of $\check{E}\hat{I}$ and jQ its imaginary part.

These 2 diagrams are given in Figs. 5 and 6. The diagram of Fig. 5, following eq 8, may be called the *instantaneous energy flow vector diagram*, while Fig. 6, following eq 9, may be called the *component power and reactive volt-ampere vector diagram*. The sum of the projections of Fig. 6 on the real axis corresponds in value and time with the projections of Fig. 5 on the real axis. These diagrams are based on circuits having kinetic energy in operation. Similar diagrams for circuits having potential energy are shown in Figs. 7 and 8, and the same eqs 8 and 9 apply, Q in this case being negative.

In eq 4 if we take $i = I \cos \omega t$, where I is the maximum instantaneous value of i,

$$Ri^2 = RI^2 \cos^2 \omega t$$
$$= \frac{RI^2}{2} + \frac{RI^2}{2} \cos 2\omega t$$



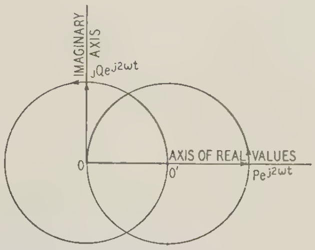
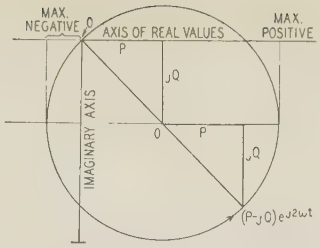


Fig. 5. (Left) Vector diagram of instantaneous energy flow, as expressed by eq 8 for resistance and inductance in series

Fig. 6. (Right) Vector diagram of component power and reactive volt-amperes as expressed by eq 9 for resistance and inductance in series



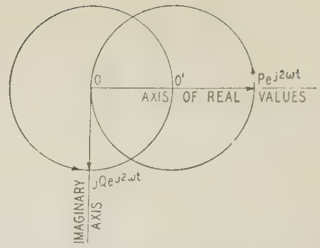


Fig. 7. (Left) Vector diagram of instantaneous energy flow, as expressed by eq 8 for resistance and capacitance in series

Fig. 8. (Right) Vector diagram of component power and reactive volt-amperes as expressed by eq 9 for resistance and capacitance in series

$$1/2\, Li^2 = \frac{1}{2} LI^2 \cos^2 \omega t$$

$$\frac{d}{dt}\left(\frac{1}{2} Li^2\right) = -\omega LI^2 \cos \omega t \sin \omega t$$
$$= -\frac{1}{2} LI^2 \sin 2\omega t$$
$$= \frac{1}{2} LI^2 \cos\left(2\omega t + \frac{\pi}{2}\right)$$

Flow of energy

$$= \frac{RI^2}{2} + \left\{\frac{RI^2}{2} \cos 2\omega t + \omega \frac{LI^2}{2} \cos\left(2\omega t + \frac{\pi}{2}\right)\right\} \tag{10}$$
$$= \frac{RI^2}{2} + \left(\frac{RI^2}{4} + j\omega \frac{LI^2}{4}\right) e^{j2\omega t} + \left(\frac{RI^2}{4} - j\omega \frac{LI^2}{4}\right) e^{-j2\omega t}$$
$$= \left\{\left(\frac{RI^2}{4} + j\omega \frac{LI^2}{4}\right) + \left(\frac{RI^2}{4} + j\omega \frac{LI^2}{4}\right) e^{j2\omega t}\right\} + \left\{\left(\frac{RI^2}{4} - j\omega \frac{LI^2}{4}\right) + \left(\frac{RI^2}{4} - j\omega \frac{LI^2}{4}\right) e^{-j2\omega t}\right\}$$

Choosing positive rotation for vector representation of power we have

$$\text{Flow of energy} = \frac{RI^2}{2} + j\omega \frac{LI^2}{2} + \left(\frac{RI^2}{2} + j\omega \frac{LI^2}{2}\right) e^{j2\omega t}$$
$$= \check{E}\hat{I} + \check{E}\hat{I}e^{j2\omega t} \tag{11}$$
$$= \check{E}\hat{I} + \check{E}\check{I}$$

Eqs 9 and 10, and the component circle diagram Fig. 6 correspond. Eqs 8 and 11 are those for Fig. 7 which is a single circle diagram giving the instantaneous power or flow of energy.

Single Phase Non-Sinusoidal Electromotive Forces and Currents

In the solution of linear circuits with non-sinusoidal electromotive forces applied it was shown that each harmonic of electromotive force is considered independent of the fundamental electromotive force and the other harmonics. Each harmonic therefore has its own power input, stored energy cycle, reactive volt-amperes, and power factor as if the others did not exist. If we consider the harmonic reactive volt-amperes with respect to the fundamental reactive volt-amperes, it is seen that the integral of the even harmonics

over $^1/_2$ cycle of the fundamental reactive volt-amperes is always zero, and for the odd harmonics will vary from zero up to the integral of $^1/_2$ a harmonic reactive cycle. The amount added to the reactive volt-amperes during $^1/_2$ cycle of fundamental reactive volt-amperes for each harmonic is zero for all even and zero to $\pm\frac{1}{\pi}$ the integral over $^1/_2$ cycle of the odd harmonic, depending upon the phase position with respect to the fundamental reactive volt-ampere cycle. The contribution to the fundamental reactive volt-ampere cycle of the harmonic therefore is indeterminate from the root mean square volts and amperes showing that there is no such thing as the equivalent sine wave for non-sinusoidal currents and electromotive forces.

If the wave form of applied electromotive force is known the stored energy cycle for the fundamental component current and its harmonics are completely defined, and therefore the respective power inputs, reactive volt-amperes, and instantaneous powers are known for each harmonic and the whole instantaneous power cycle and fundamental reactive volt-ampere cycle can be obtained by composition of their individual values as pointed out, but the values obtained in this way cannot be derived from the mere measurement of the root mean square volts and amperes of the circuit.

In practical circuits the distortion is usually negligible and therefore power factor as defined should be retained as a convenient practical measure of the ratio of mean volt-ampere to mean power input or mean rate of dissipation. For analytical work where harmonics are large in comparison with the fundamental, equivalent sine waves should never be used, but each harmonic should be considered independently.

Power and Reactive Volt-Amperes in a Single-Phase Linear Network

The method of obtaining power and reactive volt-amperes for a linear single-phase network may be generalized by using the Lagrangian energy function and Rayleigh dissipation function. If i_1, i_r, i_n are the instantaneous currents flowing into n terminals of the network and if it is supposed that the Lagrangian function $T-W$ (where T is kinetic energy and W is potential energy) and the dissipation function F have been expressed in terms of the terminal currents, then

$$\text{Instantaneous power input at } r^{th} \text{ terminal} = i_r \frac{\delta F}{\delta i_r}$$

$$\text{Instantaneous inflow of stored energy} = \left(\frac{d}{dt}\frac{\delta(T-W)}{\delta i_r} - \frac{\delta(T-W)}{\delta q_r}\right) i_r$$

$$\text{Instantaneous power input} = \left\{\frac{\delta F}{\delta i_r} + \frac{d}{d_t}\frac{\delta(T-W)}{\delta i_r} - \frac{\delta(T-W)}{\delta q_r}\right\} i_r$$

This expression is quite general and applies for both sinusoidal and non-sinusoidal currents, and when the terminals supply induction motors and synchronous motors as well as simple impedances. For sinusoidal waves it gives the same result as the vector expression

$$P_r + jQ_r = \check{E}_r\hat{I}_r + \check{E}_r\check{I}_r$$

which has been shown to be the vector representation of instantaneous power.*

Power, Reactive Volt-Amperes, and Power Factor of Polyphase Circuits

It is not necessary to consider the general polyphase system. It is sufficient for practical purposes to deal with the three-phase system. Here as shown in "Polyphase Power Measurements" by C. L. Fortescue, A.I.E.E. Trans., v. 42, 1923, p. 358–71, the system if sinusoidal can be completely characterized by the use of the sequence symbols S^0, S^1, S^2, and the conjugate symbols S^0, S^{-1}, S^{-2}, the zero sequence system being self conjugate. Thus the currents are given in all phases by

$$S^0\check{I}_{A0} + S^1\check{I}_{A1} + S^2\check{I}_{A2}$$

A being the principal phase, and the electromotive force

$$S^0\check{E}_{A0} + S^1\check{E}_{A1} + S^2\check{E}_{A2}$$

Power as in single-phase circuits is defined by $\check{E}\hat{I}$ so that total power is

$$\Sigma(S^0\check{E}_{A0} + S^1\check{E}_{A1} + S^2\check{E}_{A2}) \quad (S^0\hat{I}_{A0} + S^{-1}\hat{I}_{A1} + S^{-2}\hat{I}_{A2})$$

which gives

$$\begin{gathered}3(\check{E}_{A0}\hat{I}_{A0} + \check{E}_{A1}\hat{I}_{A1} + \check{E}_{A2}\hat{I}_{A2}) + \\ \Sigma(S^{-1}\check{E}_{A0}\hat{I}_{A1} + S^{-2}\check{E}_{A0}\hat{I}_{A2} + S^1\check{E}_{A1}\hat{I}_{A0} + S^2\check{E}_{A2}\hat{I}_{A0}) + \\ \Sigma(S^{-1}\check{E}_{A1}\hat{I}_{A2} + S^1\check{E}_{A2}\hat{I}_{A1})\end{gathered}$$

The instantaneous sum of the expressions having S^{-1}, S^{-2}, S^1, and S^2 preceding them is zero. They are the quantities which define the interchange of power and reactive volt-amperes among phases. This is characteristic of unbalanced polyphase systems and unbalance factors are associated with those interchanges.

If we take the product

$$(S^0\check{E}_{A0} + S^1\check{E}_{A1} + S^2\check{E}_{A2}) \quad (S^0\check{I}_{A0} + S^1\check{I}_{A1} + S^2\check{I}_{A2})$$

we obtain

$$\begin{gathered}\Sigma S^2\check{E}_{A1}\check{I}_{A1} + S^1\check{E}_{A2}\check{I}_{A2} \\ \Sigma S^1\check{E}_{A0}\check{I}_{A1} + S^2\check{E}_{A0}\check{I}_{A2} + \\ 3\check{E}_{A0}\check{I}_{A0} + 3(\check{E}_{A1}\check{I}_{A2} + \check{E}_{A2}\check{I}_{A1})\end{gathered}$$

It will be observed that the first term is the total inflow of reactive volt-amperes for each balanced system comprising the symmetrical coordinates, except the zero sequence term, and these are zero since they are preceding by S^1 and S^2 showing that the total flow of energy is uniform in a balance system. The terms $3\check{E}_{A0}\check{I}_{A0} + 3(\check{E}_{A1}\check{I}_{A2} + \check{E}_{A2}\check{I}_{A2})$ are connected with the interchange of power and reactive power between phases and it is seen that these double frequency products are not zero. The flow of power in an unbalanced polyphase system is not uniform. The equation gives the average power factor of each symmetrical component of an unbalanced system and of course if the system is

*In ordinary linear networks the total inflow of stored energy can be expressed simply as follows: Total instantaneous inflow of stored energy $= \frac{dT}{dt} + \frac{dW}{dt}$. The portion of this to be assigned to the rth terminal is that part of $\frac{dT}{dt}$ containing i_r and that part of $\frac{dW}{dt}$ containing q_r. For the instantaneous power input at the rth terminal the quantity $\frac{\delta F}{\delta i_r}$ must be added.

balanced, zero and negative sequence are not present and the expression $\Sigma S^0\check{E}_{A1}\hat{I}_{A1} = 3\check{E}_{A1}\hat{I}_{A1}$ gives not only the mean power but also the reactive volt-amperes which divided by 3 is the reactive volt-amperes per phase. Space does not permit of going exhaustively into the subject of polyphase power and reactive volt-ampere measurements but the following important points should be noted.

1. In a balanced system the total instantaneous reactance volt-amperes is zero. The volt-amperes per phase are given by the imaginary part of the product $3\check{E}_{A1}\hat{I}_{A1}$.

2. In an unbalanced system there are 3 such products representing power and reactive volt-amperes of each symmetrical component.

3. In an unbalanced system supplied from a symmetrical generator the total power and reactive volt-amperes including that of the negative and zero sequence components are included in the positive sequence components so that the expressions $3\check{E}_{A1}\hat{I}_{A1}$ gives the true measure of power and reactive volt-amperes that is supplied by the generators. The individual power factor per phase of each generator must be obtained by computing the total current and total electromotive force for each phase in the regular way.

Non-Linear Circuits

The analysis of non-linear circuits is complicated mathematically so only a brief sketch of the main characteristics will be given. The fundamental characteristic of such circuits is that sinusoidal power taken in is partly absorbed as such and partly converted into harmonic power which is either dissipated in the system or made use of. Examples of non-linear circuits are:

1. Magnetizing circuit of transformers and other electrical apparatus using iron.
2. Mercury arc and thermionic rectifier.
3. Power arcs.

If all the power for such networks is supplied from a sinusoidal source, the total power and reactive volt-amperes delivered will be given by the power and reactive volt-ampere input of the fundamental sinusoidal impressed electromotive force.

Conclusions

Following are conclusions which may be drawn:

1. For a sine wave the dissipation cycle and the stored energy cycle are fundamental concepts and are easily obtained. The power input is given by the dissipation cycle and the inflow of stored energy by the differential with respect to time of the stored energy cycle. The sum of these 2 cycles gives the instantaneous power cycle. The vector expression for this is $\check{E}\hat{I} + \check{E}\check{I}$ the second term being double frequency. $\check{E}\hat{I}$ being equal to $P + jQ$ gives the proper point on the complex plane for the center of rotation of the positively rotating vector $\check{E}\check{I}$.

2. In 3 phase sinusoidal balanced systems the total power input from a generator is continuous. The total reactive volt-amperes is zero but per phase it is given by $\check{E}_{A1}\hat{I}_{A1} + \check{E}_{A1}\check{I}_{A1}$ vectorially. When there is unbalance the polyphase power input at an unbalanced terminal is given by $3(\check{E}_{A1}\hat{I}_{A1} + \check{E}_{A2}\hat{I}_{A2} + \check{E}_{A0}\hat{I}_{A0})$. If the source of power is a symmetrical machine the total power and reactive volt-amperes input including the power and reactive volt-amperes circulated in the system by the zero and negative sequence components are given by $3\check{E}_{A1}\hat{I}_{A1}$, and this gives the true power and reactive volt-amperes input to the system.

3. Non-linear circuits are characterized by frequency changing so that fundamental power and reactive volt-amperes are taken in and converted into power and reactive volt-amperes at higher or lower frequencies. Here again in general the power and reactive volt-amperes measured at fundamental frequency define the true power and reactive volt-amperes supplied by the sine wave generator.

The Induction Motor a Versatile Device

Formerly considered useful only for constant speed service, the induction motor is becoming a motor of almost universal application. This article describes how the general characteristics of the induction motor may be varied to meet the requirements of several typical applications, some of which would have been considered impossible a few years ago.

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THE polyphase induction motor was first announced by Tesla in 1888; and is thus some 45 years old; it demanded for its operation a polyphase system of power distribution. Prior to its inception, alternators and electric power systems were single phase, frequencies were high (120 to 133 cycles) and distribution systems were limited in many respects. The induction motor therefore ushered in a new era of electrical development which has grown and expanded to be the giant it now is.

Today, the induction motor bids fair to bring about another revolution of ideas as regards its use and capabilities. Heretofore, particularly in respect to the squirrel cage motor, it has been confined to rather restricted fields of application. Its starting characteristics and the need of special starting devices were against it. Now limited-starting-current motors such as those employing double cage rotors are overcoming these objections. The use of these across-the-line motors has encouraged the idea of throwing standard motors directly on the line, and has encouraged also the use of induction motors for applications demanding frequent starting or reversing. Formerly, the squirrel cage motor was looked upon as one to be applied only for constant speed service. Today, there are many applications where the operating range covers wide variations in speed.

Demand for adjustable speed has been met to some extent by the slipring motor. Objections to this type of motor are chiefly that the speed is not independent of the load, and that the speed reduction is obtained at the expense of efficiency. The commutator motor with variable brush spacing is essentially a slipring motor with an opposing emf substituted for a rotor external resistance and off-

Based upon "Induction Motor Versatility, Nature of Its Applications" (No. 32-93) presented at the A.I.E.E. summer convention, Cleveland, Ohio, June 20–24, 1932.

sets, in some degree, these disadvantages of the slip-ring motor. The multispeed squirrel cage motor is more simple in construction and offers several fixed speeds. It cannot give adjustable speeds in the strict meaning of the word; yet it is being more widely applied than formerly, and is finding new applications on machine tools and in many special drives.

Applications of Simple Squirrel Cage Motors

Applications of simple single-winding squirrel cage motors are of a great variety. Probably the best way to classify these applications is from the standpoint of slip and torque; the divisions which can conveniently be made for this purpose are indicated in Fig. 1 where the several characteristic torque curves shown are representative of various types of squirrel cage motors.

Under division I, curve A is that of the standard, low-slip motor. Its chief characteristic is a high pullout torque at comparatively low slip, and close speed regulation under load. Its full load slip will average about 3 per cent. Its applications are so well known that no details are given here.

Some special applications demand less than 3 per cent slip; others require a torque characteristic such that there will be a large increase in torque for a small drop in speed. In the former class belong loom motors as universally used in the textile industry. In the latter class are special centrifugal machines such as babbit pots where the load comes on the motor after it is up to speed. The large-inertia load demands a rapidly increasing torque as the speed drops, else the drop in speed will be excessive and valuable production time lost in getting the machine back up to full speed. Certain tapping machines demand this same characteristic for the same reason. Curve B of Fig. 1 indicates the type of speed-torque curve for these applications.

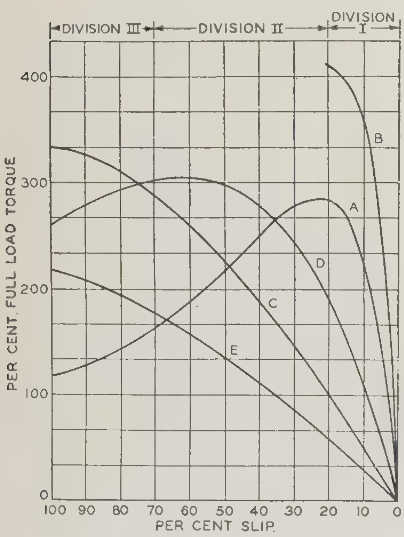

Fig. 1. Characteristic torque-slip curves of typical induction motors

Motors with comparatively high-resistance rotors (curve C) are used where high starting torque is desirable and where the excessive slip is no disadvantage. These applications include motors for hoists, cranes, elevators, conveyors, and skips. For some purposes excessive slip may be highly desirable. Applications of motors to slow-operating presses, shears, and drop hammers, where these tools are equipped with flywheels, require that the drop in speed be sufficient to allow the flywheel to restore part of its kinetically stored energy to the tool drive and thus relieve the motor. This practice allows the use of a comparatively small motor and makes for a constant power demand.

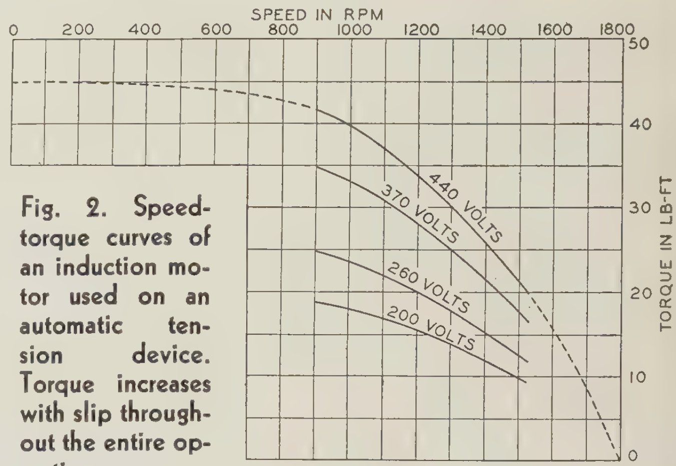

Fig. 2. Speed-torque curves of an induction motor used on an automatic tension device. Torque increases with slip throughout the entire operating range

Curve D is the torque curve of a motor with a rotor resistance between those of the motors represented by curves A and C. It has a slip of approximately 8 per cent at full load and is the motor used for average punch-press service, its high torque and slip adapting it for this work. It is used extensively for motors that must start or reverse often, such as in tapping machines, threaders, and many special applications.

Automatic Torque Control

Division II of Fig. 1 includes slips of 20 to 70 per cent. This range generally is thought to belong entirely to the slipring motor; yet squirrel cage motors also are used within this range. One interesting application is that of automatic torque control. For example, in wire drawing it is an advantage to keep a constant tension on the wire as it is reeled. If this be done, then as the reel builds up, the torque of the reel motor must increase because of the increasing radius at which this constant wire tension is to be maintained. Torque curves of a motor used for such a purpose are shown in Fig. 2. The automatic rise in torque with decrease in speed fits the motor perfectly for such applications. Only one full torque curve is shown in Fig. 2. The working portion of the lower torque curves are obtained by varying the voltage on the motor by means of a simple auto transformer. Evidently the motor can be designed to give practically any required variation in torque.

There also has been a demand for tension control in which the motor torque increases as the speed in-

creases. Such a set of torque curves is indicated in Fig. 3; again the motor may be designed to meet the requirements. In this case, the decreasing torque of the spooler motor as the spool fills up provides constant tension on the wire; but the increased torque corresponding to this constant tension is more than offset by the decreased friction and windage of the spool, so that the total desired torque falls off with the speed. If the speeds involve a high slip or cover a wide range, motors of an extremely special design may be necessary. As the motor copper losses vary with the slip, special ventilating schemes may be necessary, or recourse may be had to the slipring motor. Since the maximum-torque point can be moved about at will, any desired slope of torque curves can be had with close approximation to a straight line over the operating range.

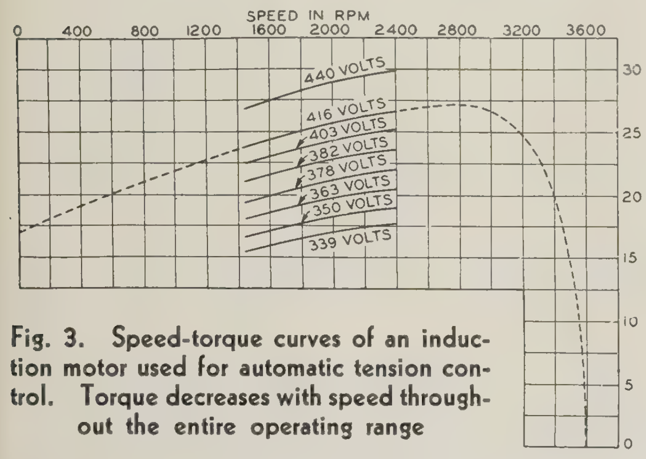

Fig. 3. Speed-torque curves of an induction motor used for automatic tension control. Torque decreases with speed throughout the entire operating range

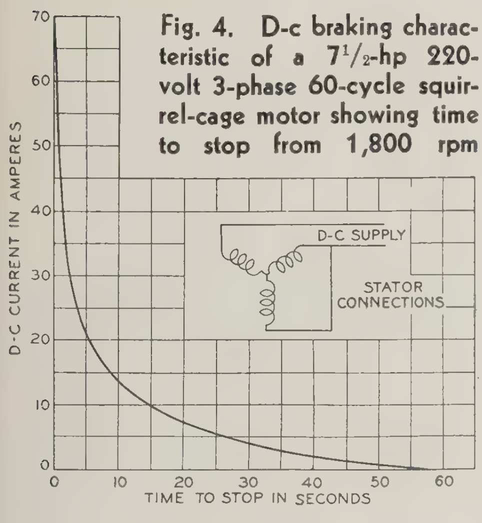

Fig. 4. D-c braking characteristic of a 7½-hp 220-volt 3-phase 60-cycle squirrel-cage motor showing time to stop from 1,800 rpm

Division III, which includes slips of 70 to 100 per cent, covers applications of induction motors where the motor makes only a few revolutions or crawls at a low speed. Such applications include valves, screw-downs, certain door-lifts such as for steel mill furnaces or hoppers, and special stalled torque motors for various types of control. The value of the starting or low-speed torque compared with the torque at higher speeds will depend on the type of motor used, as indicated in the curves of Fig. 1. The starting torque can be made to vary over wide limits by adjusting the rotor resistance. Some applications demand a high starting torque, others a low starting torque. Of particular interest in the latter type are motors of especially low starting and reversing torque as used for laundry machines. Such motors have an inherent high reactance. There are other special applications where too quick a start may result in damage to the product and which demand low starting torque. Of the opposite type are special motors for such applications as theater-lifts and tool shifts, which require abnormally high starting torques and short-time ratings.

Stopping the Squirrel Cage Motor

Division III might be extended to include stopping as well as starting characteristics. The stopping of squirrel cage motors by means of direct current offers some interesting considerations. In Figs. 4 and 5 are shown results of tests on a standard 7½-hp 60-cycle motor stopped by applying direct current to the stator. Since it would take an infinitely large current to stop a motor in zero time, the curve of Fig. 4 is asymptotic to the vertical axis. It is not asymptotic to the horizontal axis because of bearing friction. As the rotor slows down, the secondary frequency changes from that of line frequency less slip frequency, to zero frequency; thus conditions are somewhat similar to those when starting from standstill and running up to speed, where the rotor frequency changes from line to slip frequency.

The braking effort for a given value of direct current will depend on the manner in which the terminals are connected to the d-c supply. For a Y-connected stator and connection as shown in Figs. 4 and 5, the d-c ampere-turns per pole = M_1 such that

$$M_1 = \frac{N}{3} I_1 + 2\left(\frac{N}{3} \times \frac{I_1}{2} \times \cos 60°\right) = 0.5\ NI_1 \qquad (1)$$

(See "Measurement of Stray Load Loss in Polyphase Induction Motors," by C. J. Koch, A.I.E.E. Trans., v. 51, 1932, p. 756–63.)

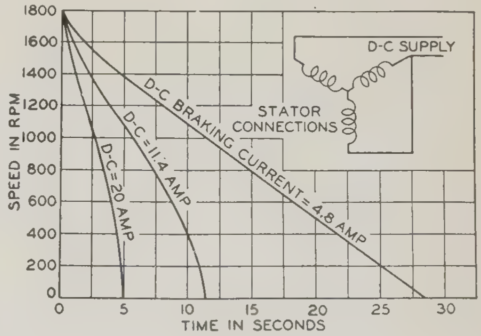

Fig. 5. Retardation curves of a squirrel-cage motor when stopped by direct current

Where only 2 terminals are used, the ampere-turns per pole are

$$M_2 = 2\left(\frac{N}{3} I_2 \cos 30°\right) = 0.578\ NI_2 \qquad (2)$$

For a Δ-connected stator and 2 terminals connected

to a common d-c line, the third being connected to the other d-c line, the ampere-turns per pole are

$$M_3 = 2\,\frac{N_0}{3}\,\frac{I_3}{2}\cos 30^\circ = 0.289\,N_0 I_3 \tag{3}$$

For a Δ-connected stator using 2 terminals only, the ampere-turns per pole are

$$M_4 = \frac{N_0}{3} \times \frac{2\,I_4}{3} + 2\,\frac{N_0}{3} \times \frac{I_4}{3}\cos 60^\circ = 0.333\,N_0 I_4 \tag{4}$$

where N and N_0 represent the turns per pole, and I_1, I_2, I_3, and I_4 represent the total direct current. It may be noted that for equal currents approximately 15.6 per cent more flux will be created by connections (2) and (4) than for connections (1) and (3). For equal voltages impressed on the different connections, (1) and (3) give the greater braking action. Although the braking ampere-turns depend on the connections as indicated in the above equations, it can readily be shown that equal ampere-turns in each case give equal heating or power consumption.

The a-c ampere-turns per pole for Y-connected stators are

$$M_5 = 0.707\,NI \tag{5}$$

and for Δ-connected stators

$$M_6 = 0.707\,N_0\frac{I}{3} = 0.408\,N_0 I \tag{6}$$

where again N and N_0 are the turns per pole and I represents the effective terminal alternating current. The ratio between d-c ampere-turns and a-c ampere-turns is thus apparent.

When a squirrel cage motor is stopped by a-c plugging, the alternating current rises from 5 to 10 times the full load current of the motor. To stop a squirrel cage motor by d-c braking also requires a current considerably greater than the rated alternating current, if the stopping is to be done in a reasonable time. The losses, however, are less for d-c stopping than for a-c plugging, with the stop accomplished in the same time in each case.

If a squirrel cage motor is stopped from different speeds by applying a direct voltage proportional to the speed, the stopping time will decrease as the speed increases. For a 2-to-1 range of speed, experiments indicate that the time to stop from the high speed will be about 75 per cent of the time to stop from the low speed.

Speed Varied by Varying Supply Frequency

An application of a squirrel cage motor to cover a wide range in speed is that of a gang of such motors driving individual units of a conveyor system where the speed range is obtained by applying variable frequency to the motors. Such cases generally require constant-torque characteristics; by applying a voltage proportional to the frequency, the torque is practically constant over a wide range of speed.

Squirrel cage motors have been applied where extremely low speeds are required by running them on frequencies as low as 3 to 5 cycles. When operated on such low frequencies, the characteristics differ immensely from those for standard frequencies. One peculiar fact is that under these conditions the locked-rotor current, no-load current, and running-load current are almost of equal value. The plugging current may be actually less than the running current if the plugging is done at the instant of low voltage.

Applications of squirrel cage motors for rapid and oft-repeated reversing or starting duty have been exceedingly active in the last few years. First came such motors applied to tapping machines, drills, and tools of a similar nature. Small planers have been equipped with 10- to 15-hp squirrel-cage multi-speed motors reversing as often as 15 times per minute. Squirrel cage motors have been used for special machine operations requiring as many as 30 to 40 reversals per minute, in order to eliminate complicated mechanical reversing mechanisms. Quite recently, motors for rapid reversing duty have been demanded for driving automatic catcher tables used in rolling sheet steel or plate (see *Iron and Steel Engineer*, v. 9, 1932, no. 5, p. 222). Characteristic curves of a 25-cycle motor for such service are shown in Fig. 6.

Fig. 6. (A, B, and C) Characteristics of a 25-cycle 375-rpm reversing motor for catcher-table service in steel mills

A. Torque-speed curve

B. Retardation and acceleration

C. Energy loss during a cycle of reversal and running

There are many other special applications of the induction motor which might be mentioned. However, enough have been indicated to show the widely diverse requirements that can be met successfully by this motor. This diversity gives to the motor a universality which will make it even more popular in the future than it has been in the past.

Protection of Polyphase Motors

Standard squirrel cage motors of moderate size have been studied to determine the protection against overheating secured by standard control devices. The results of these tests on the heating of motor windings and the temperatures at which control devices function, are presented herewith in a manner easy to follow and not complicated by the more highly theoretical considerations.

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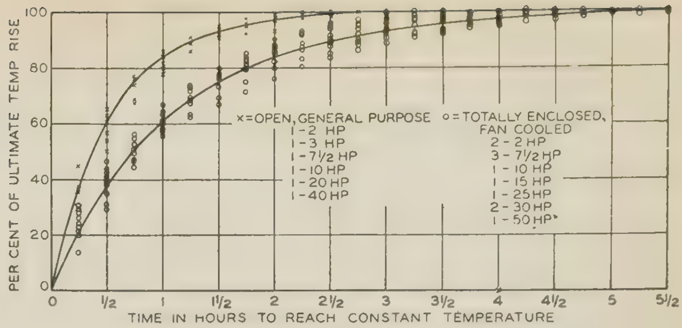
RESULTS of tests made to determine the heating of polyphase motor stator windings under various operating conditions, and to determine the maximum winding temperatures which may be attained before standard control devices will function and disconnect the windings from the line are reported in this article. In order to reach correct conclusions, it is necessary to know the relations between temperature rise and time of operation, as well as between temperature rise and load, for normal 3-phase operation and abnormal single phase operation of open and totally enclosed motors. It also is necessary to know the variation of motor current with motor load, as well as the time-current tripping characteristics of all the protective devices which ordinarily are used for protecting motors against overload.

Motor Time-Temperature Characteristics

In order to determine the relation between temperature rise and time of operation, a large number of time-temperature curves were plotted and immediately it was apparent that distinctions would have to be made between types of cooling and motor speeds in order to obtain useful empirical data. Separate curves therefore were drawn for open and totally enclosed motors and for each commercial 60-cycle speed. All tests in which the load was not absolutely constant throughout the run were eliminated from consideration. Figure 1 shows typical curves for 900-rpm motors of both open and totally enclosed construction, with the actual test points



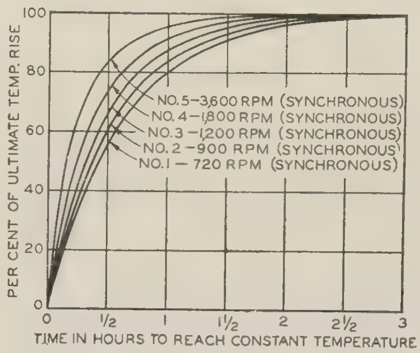


Fig. 1. (Above) Typical time-temperature curves for 900-rpm 60-cycle squirrel cage motors

Fig. 2. Average time - temperature curves for open squirrel cage motors

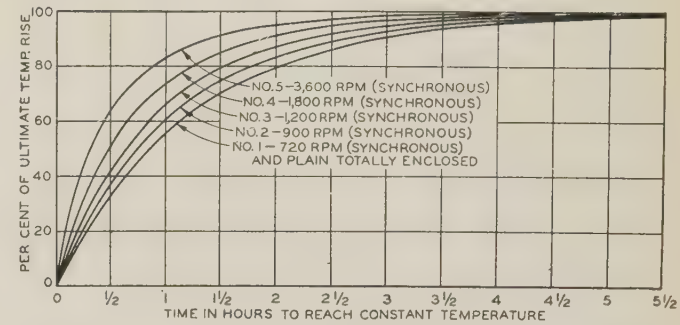


Fig. 3. Average time-temperature curves for fan cooled squirrel cage motors

indicated. Temperatures are expressed in per cent of the ultimate rise because most commercial motors operate at temperatures somewhat less than the value stamped upon the name-plate and no 2 motors have exactly the same rise. These curves cover motors ranging from 2 to 50 hp and the agreement between the various tests is fair, with a total variation between extremes of about 7 deg C on the totally enclosed and about 4 deg C on open motors.

Time-temperature curves for open general purpose motors of all speeds are shown in Fig. 2, and indicate quite clearly the results which may be obtained with effective ventilation. The same diameter of blower was used for all tests upon any frame and the volume of cooling air therefore is increased with each increase in speed. The temperature rise of higher speed motors reaches a constant value quickly due to the fact that the heat is carried off by the cooling air as well as by radiation. The effect of the larger volume of air is shown in the shapes of the curves.

Similar curves for totally enclosed motors are shown in Fig. 3. The lower curve is characteristic for plain totally enclosed motors, the cooling of which depends only upon radiation. It will be noted that

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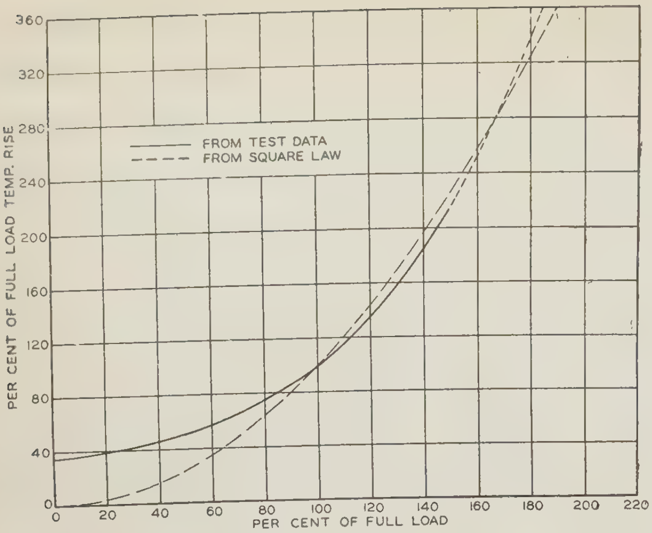

Fig. 4. Average load-temperature curve for squirrel cage motors operating polyphase

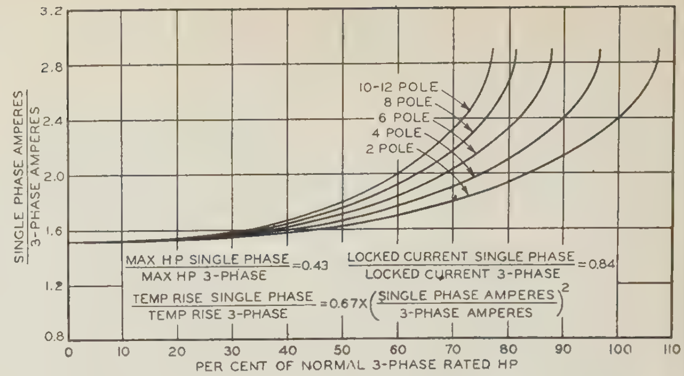

Fig. 5. Average current-load curves of 3-phase induction motors operating single phase

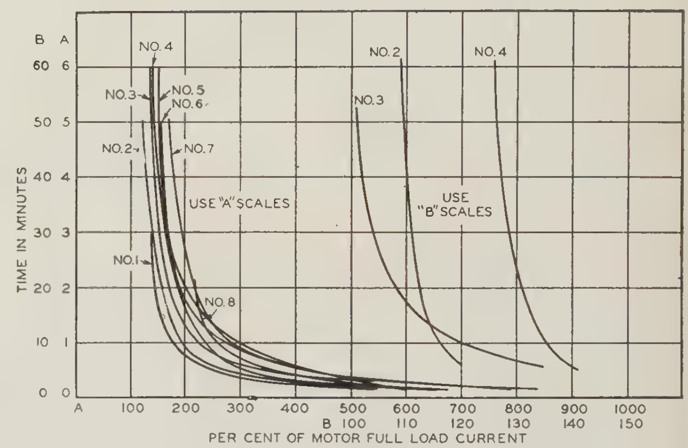

Fig. 6. Tripping characteristics of thermal overloads

the temperature rise increases very slowly and that such a motor takes a long time to reach its final temperature. The curves for fan cooled totally enclosed motors also are given in Fig. 3 and indicate the effect of the cooling air.

It is obvious that the shape of heating curves will depend upon electrical characteristics, speed, effectiveness of ventilation, and other factors which vary with the frames produced by one manufacturer, and also with the types of construction used by different manufacturers. The curves shown are probably typical and may represent average conditions. It may seem strange that motors with good ventilation reach a higher percentage of their ultimate temperature rise in a given time than do motors with poor ventilation. It must be remembered, however, that the ultimate temperature is lower, which means that for a well ventilated motor the actual temperature rise in degrees is less than that of a motor with the same electrical characteristics but with poorer ventilation.

Motor Load-Temperature Characteristics

The time-temperature curves of Figs. 1, 2, and 3 were all plotted from full load temperature tests. Similar tests made at other loads show that the variation of temperature rise with time is practically independent of load and that a motor operating at a continuous overload reaches the same percentage of its ultimate rise in a given time as it does at full load. These curves therefore may be used for all commercial conditions of load provided the ultimate temperature rise for that output is known.

The relation between temperature rise and load might be determined theoretically for a motor having only copper losses by assuming that the temperature rise varies as the watt loss, and that the watt loss varies as the square of the output. The iron, friction, and windage losses, however, are constant, and do not change with the load, so that it is desirable to determine these relations by tests. This was done and the results are plotted in Fig. 4. It is apparent that the heating is considerably influenced at light loads by the constant losses and that it varies approximately as the square of the output only at considerable overloads. When making use of this curve, it should be assumed that every motor has a full load temperature rise as specified on the nameplate, usually 40 deg C for an open general purpose motor and 55 deg C for a totally enclosed machine.

Using these curves, it is possible to approximate the probable temperature rise of the average induction motor for any load and for a given time interval, starting cold. It is possible also to estimate the temperature rise of a motor operating for a specified length of time at one output followed by another run at some other load. In the latter case it is necessary to calculate the temperature rise at the first load from time-temperature and load-temperature curves. A new pair of axes is then drawn through this point on the time-temperature curve and the temperature rise for the second load is determined by measuring time and temperature from the new axes.

Single Phasing of Motors

Up to this point, the variation of temperature rise with time and load has been determined only for normal 3-phase operation. Abnormal operating conditions of motors must also be considered, and the most important is single phasing. A 3-phase induction motor when operating single phase with a certain

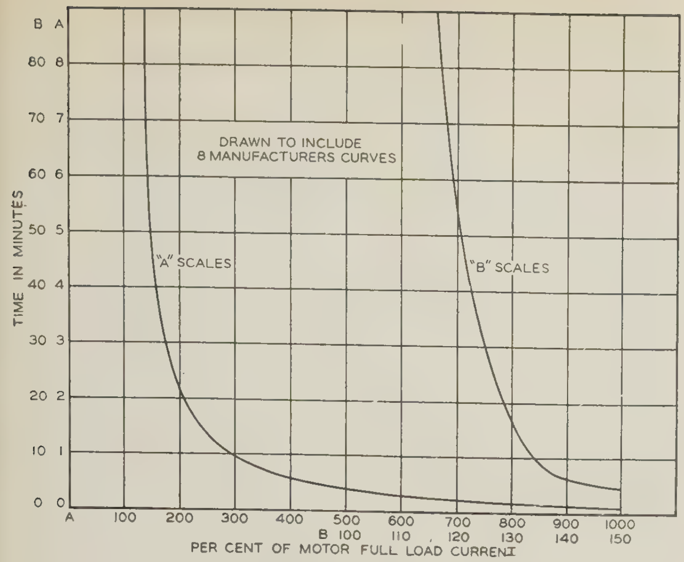

Fig. 7. Tripping characteristics of thermal overloads (maximum time)

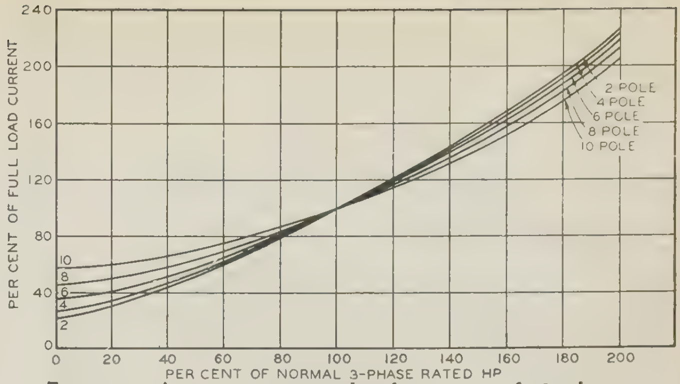

Fig. 8. Average current-load curves of 3-phase induction motors operating 3 phase

Table I—Motor Overloads Recommended with Various Thermal Overload Relays

Manufacturer	Thermal Overload Rating in Per Cent of Motor Full Load Current: Open Motor	Totally Enclosed Motor
No. 1	111	111
No. 2	108	108
No. 3	112	112
No. 4	125	125
No. 5	112	100
No. 6	115	115
No. 7	112	100
No. 8	115	100

current flowing in the stator winding will obviously have $^2/_3$ as much stator copper loss as when operating 3 phase with the same current. Tests show that the temperature rise of the stator winding under these conditions varies approximately as the copper loss, and it is quite satisfactory to proceed on the assumption that the temperature rise of a 3-phase motor when operating single phase is $66^2/_3$ per cent as much as when operating 3 phase with the same current flowing.

If it were correct to assume that the current in the stator winding of a 3-phase motor when operating single phase is 1.73 times the current which flows when operating 3 phase, and that the temperature rise varies exactly as the square of this current, it would be possible to say immediately that the temperature rise of a 3-phase motor operating single phase is $(1.73)^2 \times {}^2/_3$ or twice as much as when operating 3 phase. However, the current ratio is 1.73 for only one load, and it is desirable to determine by actual test, the variation between current ratio and load for motors of various speeds. These tests were made and the results are plotted in Fig. 5.

The current ratio is found to be about 1.5 for the average motor running light, and 1.73 at approximately half load. Beyond half load, it increases very rapidly due to the fact that the breakdown point is being approached. Figure 5 shows that the approximate single phase breakdown which may be expected from average commercial motors is about 43 per cent of the corresponding 3-phase figure. The ratio of locked currents also was determined while making these tests, and it was found that the locked current single phase is about 84 per cent of the locked current 3 phase. The single phase heating for a given horsepower load is approximately 67 per cent times the current ratio squared of the 3-phase heating for the same load.

Tripping Characteristics of Protective Devices

Thermal overload relays are most commonly used for protecting motors against overload and their wide acceptance is proof of their satisfactory performance. Each control manufacturer uses a thermal unit of his own design and there is a considerable variation in the characteristics and application of the various devices. In order to determine the extent of this variation, 8 control manufacturers were asked for the rating and calibration curves of the thermal overloads which they would recommend for protecting a motor with a certain full load current. The information which was supplied indicated that while there are no standard ampere ratings for thermal overloads, all control manufacturers recognize a standard basis of rating—an ampere rating which is the smallest current that will cause it to trip. Because there are no standard ampere ratings, the thermal units which were recommended permit various overloads to be carried by the motor as shown in Table I.

Manufacturers Nos. 5, 7, and 8 specify a thermal overload with smaller current rating for a totally enclosed 55-deg C motor than they do for an open 40-deg C motor. Certain manufacturers state that their standard thermal overloads protect polyphase motors from being damaged in case of single phase operation, while others specify thermal units of a smaller ampere rating when such a requirement must be met. The calibration curves are plotted in Fig. 6 and show a certain amount of variation but apparently not enough to justify any difference in application. In order to determine the maximum heating of polyphase motors which might result when using any of these thermal overloads, a single calibration curve, Fig. 7, was so drawn that all of the 8 curves are included within it, except that of manufacturer

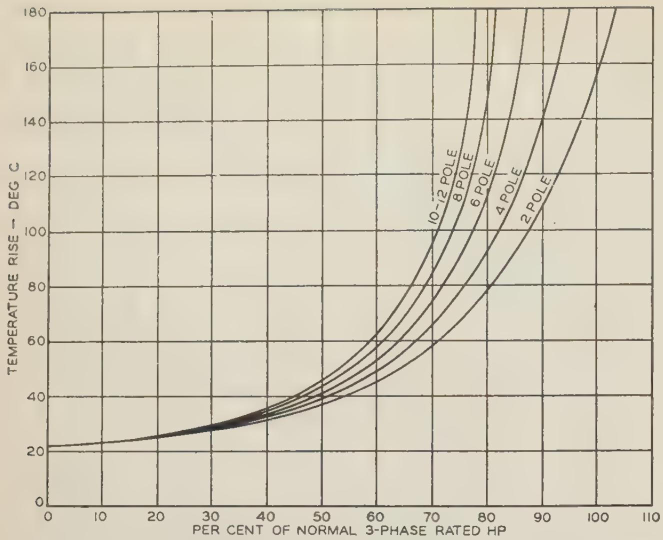

Fig. 9. Average load-temperature curves for 40-deg 3-phase motors operating single phase

No. 4. A rating of 115 per cent of the full load motor current was assumed as a reasonable average.

Magnetic overload relays are used in many kinds of motor control equipment and relays which make use of a combination of the magnetic and thermal principles are available also. Both of these types have tripping characteristics very much like those of thermal overload relays and their calibration curves fall well within the graph of Fig. 7.

Determination of Motor Winding Temperatures Permitted by Overload Relays

It is now possible to determine whether commercial overload relays, when properly selected, protect squirrel cage motor windings from damage under all operating conditions.

If a general purpose squirrel cage motor becomes locked due to some defect in the driven machine, or some other circumstance which results in a very heavy load, it will have a locked current of from 5 to 7 times full load current when all 3 phases are energized, or about 84 per cent of these values when one fuse is blown and one phase is no longer energized. With 5 times full load current, the overload relay will trip in less than $^1/_2$ min and with 84 per cent of that current, it will trip in slightly over $^1/_2$ min. Experience has shown that standard squirrel cage motors are not damaged by being locked under these conditions.

There are 2 normal running conditions which may result in dangerous winding temperatures: Operating polyphase at overloads, and operating single phase at loads much greater than half the 3-phase horsepower rating. In either case, the dangerous load may begin when the motor is practically at room temperature, or when the motor already may have reached an initial temperature at full load or at the overload permitted by the rating of its overload relays.

It is quite easy to approximate the temperature rise of a squirrel cage motor operating polyphase at overloads. The most common conditions are:

1. Motor overloaded, without adequate protection.—For instance, an open motor with a normal temperature rating of 40 deg C carrying 25 per cent overload without adequate relay protection will operate continuously and will have an ultimate temperature rise of approximately 58.5 deg C. (See Fig. 4.)

2. Motor overloaded, with adequate protection, without initial rise.—Suppose this is an 1,800-rpm motor carrying 25 per cent overload, protected by relays rated at 115 per cent of the full load motor current and starting with the motor at room temperature. Thermal relays rated at 115 per cent of full load motor current will trip in 31 min (Fig. 7, scale *B*), when the motor is carrying 25 per cent overload, assuming that the current drawn by the motor varies directly as the load. (This is an approximation but in the absence of more accurate data will give fairly satisfactory results. A closer approximation may be made by using the average current-load curves of Fig. 8.) Figure 2 shows that an 1,800-rpm motor operating under these conditions will reach about 74 per cent of its ultimate temperature, or will have a temperature rise of 43 deg C in 31 min; or at the instant the overload relays trip.

3. Motor overloaded, with adequate protection, with initial rise.—Now suppose that the same motor protected by the same relays has reached a constant temperature operating at a load which approaches 115 per cent as a limit. The motor therefore will have a temperature rise of about 50 deg C (See Fig. 4). If the 25 per cent overload is applied after this initial rise has been reached, a final temperature rise of about 55 deg C will be attained at the instant the overload relays operate. (Obtained by locating new axes in Fig. 2 at 50 deg C or 85.5 per cent of ultimate.)

It is not quite so simple to estimate the temperature rise of a squirrel cage motor operating single phase, since it is necessary to use the single-phase 3-phase current-load curves of Fig. 5 in addition to the graphs of Figs. 2, 3, 4, and 8. In order to give a clearer idea of single phase operating conditions, Fig. 9 has been calculated to show the temperature rise which may be expected in open type 3-phase 40-deg C motors when running single phase continuously. It is of interest to note that the average load which they will carry continuously under these conditions with normal temperature rise is about half of the 3-phase horsepower rating. The winding temperatures reached before the overload relays operate may be determined in the same manner as described for 3-phase operation.

The curves of Fig. 10 show the approximate temperature rise in the windings of 1,800-rpm 60-cycle squirrel cage motors at various loads and for the time interval during which overload relays rated at 115 per cent of the motor full load current will permit them to operate. The maximum temperature rise of open type 40-deg C motors operating under these conditions is 60 deg C, which added to a maximum room temperature of 40 deg C gives a winding temperature of 100 deg C. Totally enclosed fan cooled motors controlled by these overload relays may reach a winding temperature of 115 deg C. Corresponding curves may be drawn for other speeds and it would

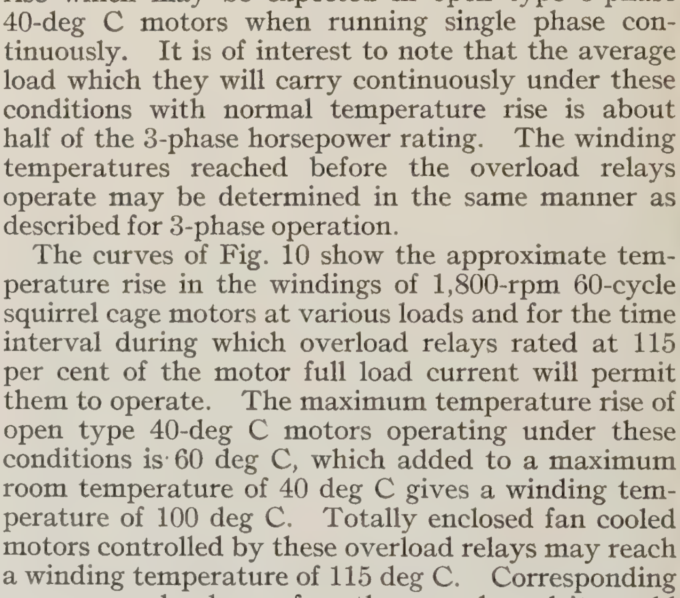

Fig. 10. Maximum temperatures attained in 3-phase motors protected by overload relays rated 115 per cent of full load current

seem that these temperatures may be slightly exceeded in 2-pole motors, but that the slower speed motors may be somewhat cooler.

Conclusions

The conclusions reached by this study may be stated briefly as follows:

1. After taking into account the fact that usually there is at least a small margin between the actual temperature rise of a motor and the guaranteed rise, that there is a certain factor of safety in the tripping curves furnished by control manufacturers, and that most of these curves are determined for overload relays starting cold, it is concluded that overload relays rated 115 per cent of full load motor currents protect open type 40-deg C general purpose motors against damage when locked, overloaded, or single phased. It is concluded that overload relays rated at more than 115 per cent of motor full load currents should not be used except when temperature tests on individual motors show conclusively that dangerous temperatures will not be reached when using such relays.

2. On account of the difference in temperature rating between open and totally enclosed motors, overload relays for the latter should be applied more closely except when temperature tests on individual motors are made and show conclusively that relays of greater rating may be used safely.

A complete study of motor heating would cover a wide field. For instance when considering motors with intermittent ratings or widely varying loads, it is necessary also to determine cooling characteristics which will depend upon whether the motor is standing still or running idle, and will vary with the speed. Heating characteristics will also change with variations in electrical types, such as elevator, punch press, and double squirrel cage motors. Motors with part-slot windings, such as 2-winding multi-speed machines, probably will have heating characteristics differing considerably from those of standard motors. This article therefore is incomplete but has been written in an attempt to present the data for standard squirrel cage motors of moderate size, in a manner which is easy to follow and without complicating the problem by any theoretical considerations which are of paramount interest only to the motor designer.

Transoceanic Radio Communication

Some 40 nations of the world are linked to the United States by the radio network of R.C.A. Communications, Inc. Satisfactory commercial operation of such a system imposes upon the plant behind the service many rigorous technical requirements, some of which are described here, and the means for meeting them disclosed.

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WITH major terminals at New York and San Francisco, and supplementary centers in Havana, Honolulu, and Manila, the R.C.A. Communications, Inc., operates a radio network interlinking the United States with about 40 other countries. When transoceanic services were opened in 1920 only 6 circuits were in use, whereas early in 1932 this total had grown to 54. This system in conjunction with branch radio circuits and wire networks in the countries served reaches practically the whole civilized world.

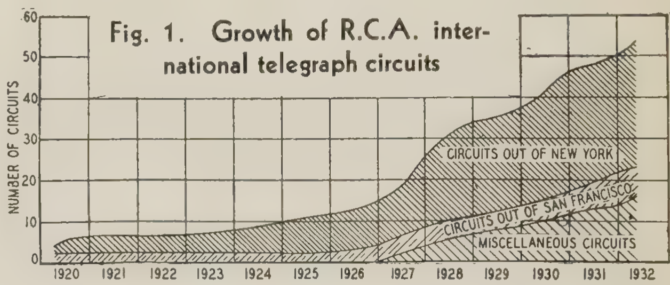


Fig. 1. Growth of R.C.A. international telegraph circuits

All 10 circuits in use by the close of 1924 were operated at the relatively low frequency of from 15 to 30 kc produced directly by means of Alexanderson alternators.[1,2,3] Since 1924, high frequencies have been used increasingly until now they carry nearly all long distance traffic, although low frequencies still are used across the North Atlantic to supplement the regular high frequency service when the latter is disturbed by occasional magnetic storms. Since 1927 the number of circuits has doubled, the rapid increase being made possible by the introduction of high frequency vacuum-tube transmitters, the first cost of which is relatively low. These transmitters are used exclusively for high frequency radiation.[4,5,6]

Equipment now in service on the Atlantic Coast includes some 8 low frequency and 35 high frequency transmitters, all controlled from New York City, and some 16 low frequency and 40 high frequency receivers to handle incoming New York traffic.[1,3,5,7,8] On the Pacific Coast are 12 high frequency transmitters controlled from San Francisco and some 20 high frequency and a few low frequency receivers to handle incoming San Francisco traffic. Transmitting and receiving stations are separated from each

Essentially full text of a paper (No. 32-115) presented at the A.I.E.E. Pacific Coast convention, Vancouver, B. C., Aug. 30–Sept. 2, 1932.
1, 2, 3. . . . References are listed at the end of the article.

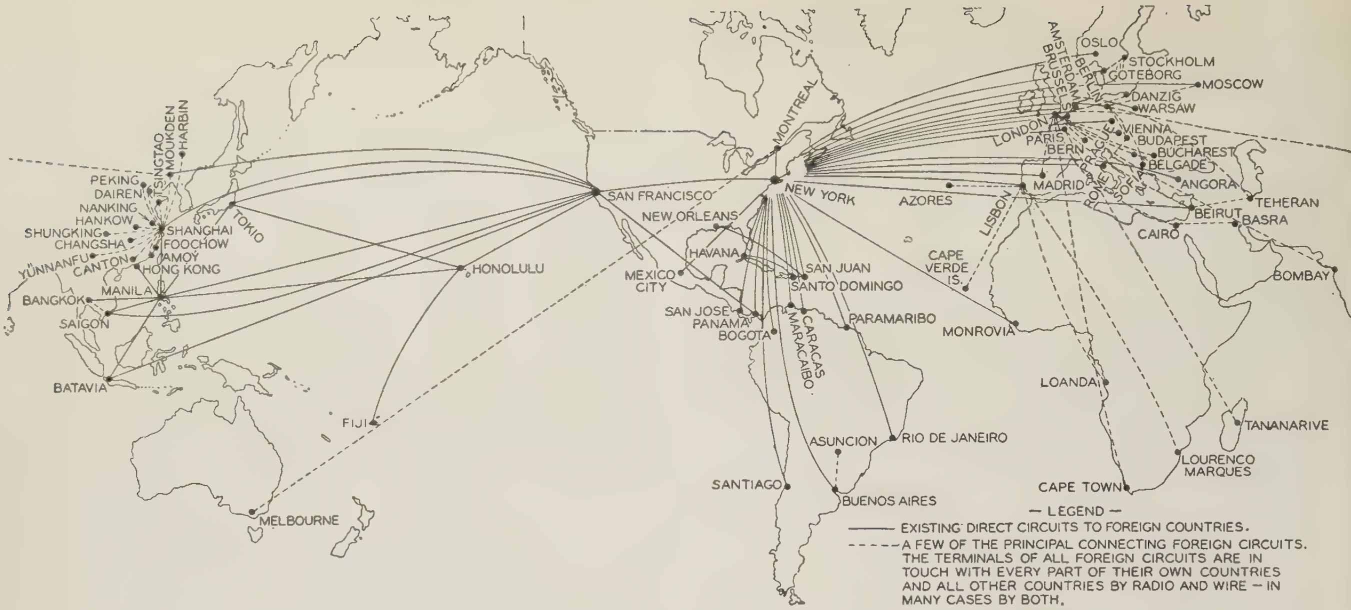


Fig. 2. A map of the principal portion of the world showing the R.C.A. international circuits

other and usually are some distance from the centralized traffic offices in the associated terminal cities.

Central Office Equipment

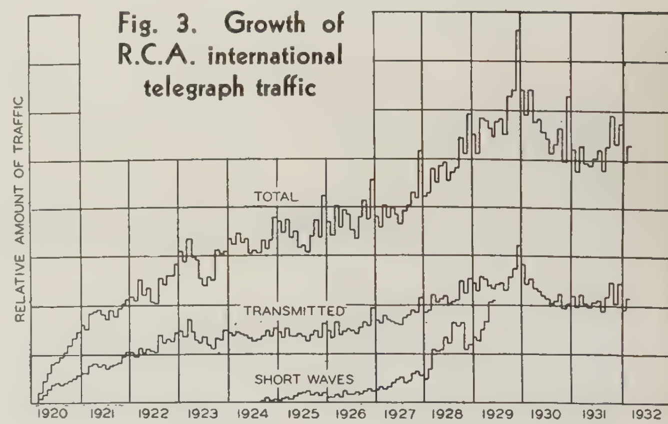
All traffic operations are centralized in traffic offices conveniently located in terminal cities and connected by wire lines with the transmitting and receiving stations. Messages to be sent are transferred to paper tapes by means of perforators having keyboards similar to ordinary typewriters. The perforated tape then is fed through automatic transmitters which impress the dots and dashes of the Continental Morse code upon the control lines to the transmitting stations. The speed of transmission ranges from 5 to 200 words per minute, depending upon circuit conditions and traffic load. On busy circuits a speed of 100 to 125 words per minute usually is maintained.

Signals from the receiving station arrive at the central offices in the form of keyed tones. These are amplified, rectified, and then plugged through to any desired receiving table to operate an automatic recorder. The recorder has a light movable coil suspended in a strong magnetic field. Signal currents through this coil cause it to move a light lever carrying a small silver tube through which ink is impressed upon a moving paper tape. The signals appear as undulations in ink line upon the tape.

Tape bearing the signals is drawn at a convenient speed across a guide on the operator's typewriter from which the operator reads the messages and types them on message blanks. If the circuit operates faster than 50 or 60 words per minute, 2 or more operators may divide the tape between them. In this way the messages on all circuits are kept transcribed and there is no delay.

The typed messages are carried on a belt conveyor to a central point where they are timed, numbered, routed according to destination, enveloped, and dropped through a chute to the messenger room for immediate delivery.

Fig. 3. Growth of R.C.A. international telegraph traffic



Transmitting Stations

Fundamentally, the purposes of the transmitting stations are to:

1. Convert 60-cycle a-c power into power of radio frequencies.
2. Radiate the radio frequency power.
3. Accurately control the radiation frequency.
4. Modulate or key the radiation for the transmission of intelligible signals.

For low frequency transmission an Alexanderson alternator driven by a 2.2-kv 2-phase wound-rotor induction motor is used to produce energy at from 15 to 30 kc. The alternator is of the inductor type with a toothed rotor running between parallel armatures bearing 64 armature coils. The outputs of the 64 coils are combined into a single circuit by means of a transformer which delivers from 100 to 120 amp at 2 kv to one of several downleads and tuning coils of an Alexanderson multiple tuned antenna.

Each of the 2 multiple tuned antennas at the Rocky Point transmitting station is 1.5 miles long and consists of 12 conductors carried on 150-ft crossarms, supported on steel towers 410 ft high, and spaced about 1,250 ft apart. When a signal is

Fig. 4. Portion of operating room at New York central office

A belt conveyor serves each of the 2 double rows of tables shown; one side of each table is for transmitting and the other for receiving. Transmitting and receiving operators handling messages with any one country are placed together to facilitate circuit handling

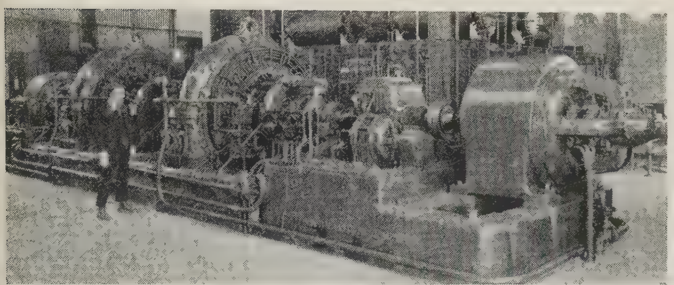


Fig. 5. 200-kw Alexanderson high frequency alternators at the Rocky Point, N. Y., station

being transmitted, the circulating energy in each of these antennas is about 700 amp at 135 kv, or nearly 100,000 kva, a figure that indicates the magnitude of the power required for long distance commercial radio communication. Although each of these antennas constitutes a circuit with an extremely low power factor (for its frequency) its radiation efficiency is only about 10 per cent and its directive effect is practically nil.

In high frequency transmitters, vacuum tubes are used to convert 60-cycle power into direct current and then into power of about 5,000 to 22,000 kc. The tubes that produce the radio frequencies are equivalent to resistances, the value of which may be varied with extreme rapidity by varying the potential upon control electrodes within the tubes.

Nearly all of our high frequency transmitters employ relatively low powered piezoelectric crystal-controlled oscillators to produce initial oscillatory currents at frequencies between about 750 and 3,000 kc.[9] The oscillator output then is passed through a chain of vacuum tube amplifiers and frequency multipliers to obtain the final power and frequency required for transmission. The crystal oscillator provides a practically constant frequency and permits the operation of transmitters with relatively small frequency separation. The Federal Radio

Fig. 6. A group of 20–40-kw short wave transmitters at Bolinas, Calif., station

Commission limits the frequency variations to less than 0.05 per cent on old equipment and 0.02 per cent on new equipment.

The use of frequency multiplication in the successive stages of amplifier greatly reduces the tendency for high power circuits to feed energy back to lower power circuits in a way to set up uncontrolled self-oscillations in the amplifier system. This is an important feature and is almost a necessity where large power amplification is used. The use of screen grid shielded vacuum tubes and neutralizing circuits for counteracting couplings between tube input and output circuits also are helpful in preventing spurious oscillations. The final power outputs to the antennas range between about 1 and 50 kw depending upon the circuit requirements.

Keying of the transmitters in accordance with telegraph signals is done by varying the electrode potentials on some of the vacuum tubes in the chain of amplifiers. This is done through electromechanical relays or through vacuum tube devices controlled from the central office. Some of the vacuum tube keying equipment is capable of functioning at speeds equivalent to more than 1,000 words per minute, and is used at these high speeds in the transmission of pictures or "photoradiograms."

The use of high frequency radiation, with its shorter electrical wave lengths, has made practical and economical the directing of radiation toward the distant receiving station. Consequently, directive antennas commonly are used with high frequency transmitters.[10] R.C.A. Communications, Inc., has developed and applied successively 4 different types of directive antennas, namely, models *A* and *B*, which radiate vertically polarized waves, and models *C* and *D*, which radiate horizontally polarized waves. The power gain due to directivity ranges up to 80 to 1, depending upon the type and size of antenna. Because of their relatively low cost and great directivity, these antennas give a high ratio of circuit improvement per dollar of cost.

In Fig. 7 are shown the directive characteristics of a 2-bay model *D* antenna giving a power gain of about 80 to 1 over a half-wave dipole at the same

height as the antenna. When used with a 40-kw transmitter this antenna launches radiation toward the distant receiver equivalent to that which would be obtained with 3,200 kw in a non-directive antenna. This is about 800 times the radiation launched toward the distant receiver from an Alexanderson alternator and low-frequency multiple-tuned antenna.

Fading of high frequency signals is a phenomenon of nature which must be overcome in a commercial radio communications system. Often the received signals vary over a great range in intensities, variations at times so rapid as to constitute an audio modulation. Since observations have shown that the fading of even slightly different frequencies is not simultaneous, the effects of fading can be reduced by transmitting the same signals on more than one frequency. In some commercial transmitters the carrier wave is amplitude- or frequency-modulated at an audio rate, in addition to the keying, to produce side frequencies and so reduce fading by frequency diversity. However, it is preferable to reduce the effects of fading by methods applicable at the receiver.

Receiving Stations

The function of the receiving station is to select the desired signals by virtue of frequency discrimination and amplify and convert them to a form of electrical energy suitable for transmission over circuits extending to the central office. In the fulfillment of

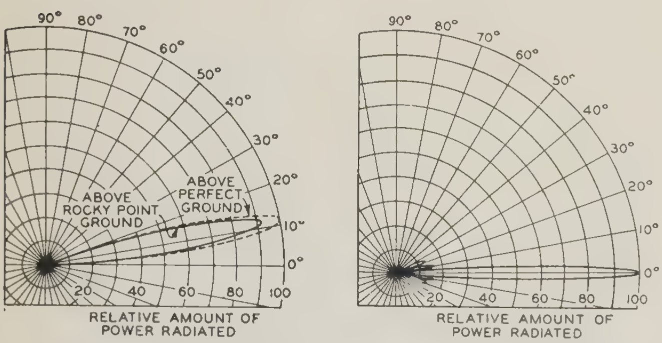


Fig. 7. Polar diagrams showing power distribution for the 2-bay model D antenna: in a vertical plane (left) and in the plane of the beam (right)

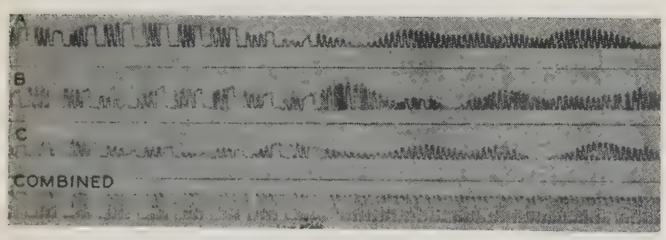


Fig. 8. Simultaneous recorder tapes showing random fading at 3 spaced antennas

A 19,180-kc signal from Portugal as inscribed simultaneously by 4 ink recorders at Riverhead, N. Y. The 3 upper strips of tape represent the signal as received on 3 different receiving antennas situated at spaced points; the lower strip reveals the result of combining the outputs of the 3 individual receivers

this function, several technical conditions must effectively be dealt with.

Signal fading already has been mentioned as one of the problems confronted in the operation of short wave circuits. Aside from the short-period fading mentioned previously there are even greater ranges in intensity changes at a diurnal rate. The diurnal variations are overcome by the use of more than one frequency channel to carry a 24-hr circuit. For example, the circuit from New York to Buenos Aires, operates on 20,455 kc during daylight hours and on 8,809 kc at night. Some of the circuits from New York to Europe require 3 properly chosen frequencies to insure reliable service.

Short-period fading is overcome by means of automatic volume control and by a "diversity" system[8] of receiving with antennas spaced usually well over 10 wave lengths apart. Automatic volume control is a form of automatic voltage regulation wherein the rectified signal is caused to react upon the overall gain of the receiver in a manner that increases the gain as the signal strength decreases.

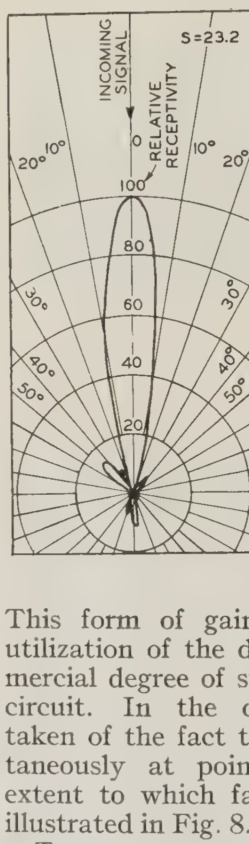
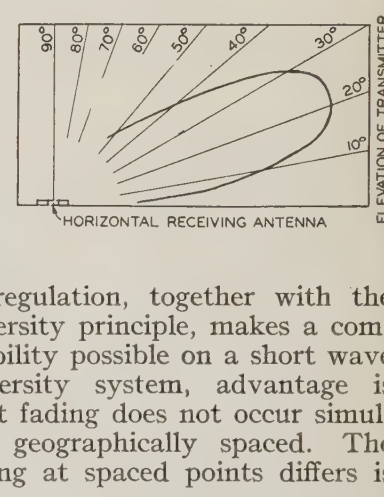


Fig. 9. Polar diagrams showing directivity of receiving antenna as observed in a horizontal plane (left) and in a vertical plane (below)

Both diagrams were obtained experimentally by recording the strength of signals received from a transmitter carried in an airplane flying at a distance of a few miles from the receiving antenna



This form of gain regulation, together with the utilization of the diversity principle, makes a commercial degree of stability possible on a short wave circuit. In the diversity system, advantage is taken of the fact that fading does not occur simultaneously at points geographically spaced. The extent to which fading at spaced points differs is illustrated in Fig. 8.

To prevent mutual interference between the various receivers each unit is carefully shielded and battery power to each circuit is fed through low-pass filters. All receivers in a station usually are operated from a common battery system continuously charged through filter circuits.

The amount of improvement possible with the space diversity system is dependent upon the range of fading. Thus, if there is no fading, one antenna will do as well as 3 combined. If, however, the signal periodically fades to zero, no amount of gain in a single receiver can give a signal free of drop-outs, while the diversity system might give continuous

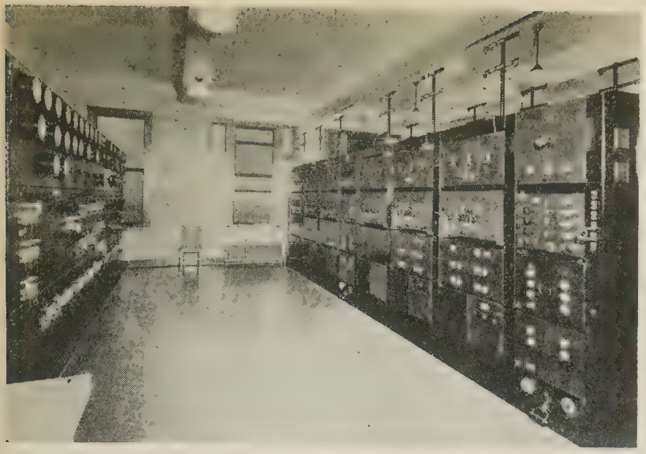


Fig. 10. Front view of rack containing 2 complete diversity telegraph receivers, Point Reyes, Calif.

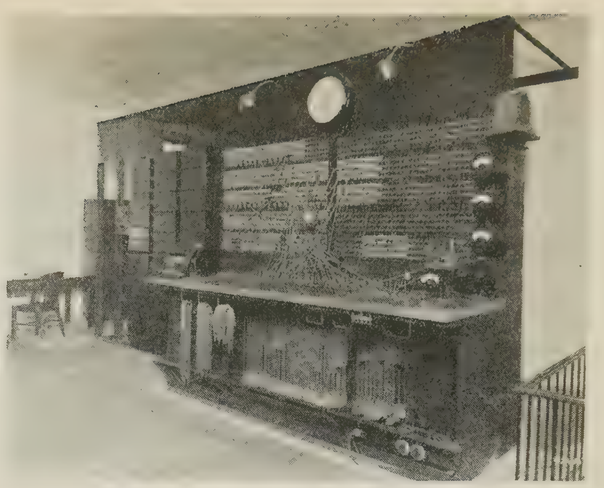


Fig. 11. Wire line control board in the receiving station at Riverhead, N. Y.

output. In practice the improvement arising from diversity comes somewhere between these 2 extremes. As a general rule a 3-antenna diversity system will give an improvement of approximately threefold as compared with a single antenna system.

Another quality that becomes apparent in the operation of a diversity system is the matter of reserve apparatus on a given channel. Some of the adjustments of a short wave receiver are so critical that, in making a retune, the signal might be lost momentarily due to error of judgment. With 3 receivers normally carrying the circuit, any 2 will carry the signal fairly satisfactorily while the receiving engineer makes an adjustment of the third. This enables more continuous operation of the circuit—important where high traffic capacity is contemplated.

Directive receiving antennas commonly are used to exclude as much as possible of the undesired radiations such as atmospherics and locally generated disturbances. These antennas are aperiodic, enabling the simultaneous receipt of signals of different frequencies, but their directivity requires the use of separate antenna systems to care for the circuits coming from different directions. At Riverhead, N. Y., for example, there are 39 antennas comprising 13 systems of 3 spaced antennas each. In Fig. 9 are shown typical diagrams of horizontal and vertical selectivity. The area of the polar diagram is a measure of the ability of the antenna to reduce the noise level. The factor S, indicated as 23.2 on this diagram, is the ratio of the area of the circle to the area of the polar diagram. This ratio is the numerical improvement in signal to noise power ratio due to directivity if the noise sources are uniformly distributed about the receiving site. Expressed in transmission units, the improvement would be 13.9 db.

Directivity in the vertical plane as determined experimentally by an airplane at 3 miles distance is shown at the right in Fig. 9, where a marked discrimination against radiations originating at ground level may be noted. This property is of decided importance because locally generated disturbances usually emanate from points at substantially ground level.

To reduce the amount of radio frequency voltage induced directly into the transmission lines, a special design is used wherein 4 wires constitute one line, the opposite corners being connected in parallel. The electrical center of the 2 sides of this line are nearly coincident, and consequently the pickup is small.

Passing into the receivers and through the tuned radio frequency amplifiers, the signals are heterodyned to audible frequencies. Most of the selectivity of the receivers is obtained in the audio frequency stages. By means of low pass filters, it has been found practical to reduce the band width to 6,000 cycles and with increasing stability of transmitter frequencies, it should be possible eventually to reduce this band width still further.

All signals, both long-wave and short-wave, pass through the tone line control board at Riverhead (Fig. 11). All orders from the central office are passed to the supervisor at this control board, who, through the medium of a public address system, issues orders to the engineers at the receivers in both the short-wave and long-wave buildings.

By operating a telephone key the supervisor can listen to any signal and at the same time observe an indicator showing the volume of signal going into the line. Any signal can be monitored also on an ink recorder for checking telegraphic signals, or on a facsimile visual recorder in the case of facsimile signals. The facsimile recorder is used for checking outgoing signals from Rocky Point, as well as incoming facsimile signals from London and Berlin. Because of the very high speed at which facsimile signals key the transmitter, the visual recorder is especially necessary for checking the adjustment of both the receivers and the transmitters.

The principle of diversity reception also has been applied to telephony. Because of the higher modulation frequencies involved, the problem of bringing together the outputs of several antennas in such a manner as to be independent of phase is more difficult in the case of telephony than in the case of telegraphy. In other words, experience has shown that different frequencies not only fade differently, but that the phase relations between the various

frequencies varies as a result of changes in the transmission medium. As might be expected, the random changes in phase relations have been found to increase for increasing differences in frequency. Consequently, the telephonic currents received from one antenna are likely not to have any definite phase relations with respect to the currents received from a similar antenna spaced some distance away, and hence little is to be gained by adding the outputs of 2 or more receivers together during times when the fading is most severe.

In general, however, the antenna with the greatest signal strength at any moment may be expected to deliver the best quality at the output of the receiver. A simple arrangement that has been devised to select automatically the receiver having the strongest signal involves the use of 3 spaced antennas associated with 3 separate receivers.[12]

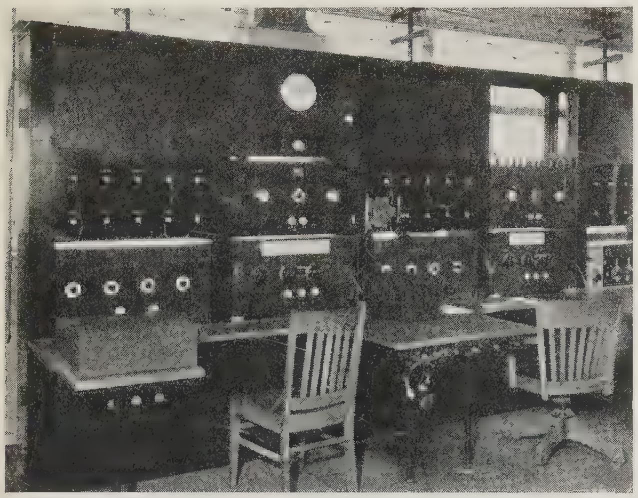


Fig. 12. A portion of the frequency measuring laboratory at Riverhead receiving station

The signal outputs from each antenna pass through separate superheterodyne receivers to the grids of individual second detectors. The plate circuits of these second detectors are energized by one battery feeding current through a load resistor common to all. This load resistor is connected between ground and the negative end of the plate supply battery, and with the audio frequency output taken from across the resistor. The voltage drop across this resistor also is applied, through a time-constant circuit, to the control-grid bias of the high frequency amplifier tubes of all sets, thus affecting simultaneously the automatic volume control of all receivers.

The second detectors are operated with the grids biased considerably negative, so that the output is approximately proportional to the square of the input voltage. Consequently, the detector having the greatest input will contribute most of the combined output. Thus, if the signal strength from one antenna is twice that of another, its receiver will contribute 4 times as much to the combined output as will the others. Consequently, as the signal carriers fade up and down in a random manner at the several spaced antennas, the receiver with the strongest carrier reduces the output from the other receivers, and, in this manner, an effective switching action is produced. The time-constant circuit may be adjusted to operate at any rate required to handle different classes of fading.

The diversity telephone receiver just described has been used for some time at Riverhead, N. Y.; Point Reyes, Calif.; and Koko Head, Territory of Hawaii, for handling addressed program material for international broadcast purposes. Many of these programs have been put on the coast-to-coast networks of the National Broadcasting Company and the Columbia Broadcasting Company during the past 3 years.

Frequency Measuring

To meet the increasing necessity for channel operation within narrow limits of frequency tolerance, precision apparatus now is in service at Riverhead, Rocky Point, and Point Reyes for accurately measuring the frequency of any given radio signal (Fig. 12). Measurements are made by a process of direct comparison with the harmonics of a base frequency of 100 kc generated by a crystal controlled oscillator of high stability. The local standard is known to be accurate to considerably better than one part in one million and the observational errors are made negligibly small.[11]

At Riverhead an average of approximately 6,000 measurements per month are made with 2 operator's positions. Not only have these measurements proved useful in supervising the performance of transmitters, as distant as Manila, but by providing ready and reliable information as to the stations involved, they have been indispensable in resolving such cases of interference as occur on various circuits. This is available not only as of the time the interference is experienced, but also from thousands of routine measurements that are taken regularly and supplied to the R.C.A. central frequency bureau. At the frequency bureau continuous records are maintained of the history and performance of more than 1,000 active high frequency stations throughout the world. Records are kept also of the frequencies on which some 5,000 additional stations are projected or are occasionally measured.

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Equipment for Electrical Precipitation

Vacuum tube rectifiers have proved their superiority over mechanical rectifiers for supplying high voltage direct current for the precipitation of solids and liquids from gases by electrical means. In this article the general requirements for this service are outlined and a typical vacuum tube installation described.

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WITH the extension of the field of application of electrical precipitation, a need has arisen for a d-c power supply that will be more satisfactory than the present common mechanical high voltage rectifier. Vacuum tube rectifiers have been found to meet the requirements of this service and have many important advantages over mechanical rectifiers. Several installations utilizing vacuum tube rectifiers already have been made. Experience to date indicates a higher recovery per kilowatt input than is obtained with mechanical rectification. An additional advantage of vacuum tube rectifiers for this service is the possibility of providing automatic control for maintaining constant current in the precipitator unit.

Application of a strong electrostatic field accompanied by corona discharge to the cleaning of gases was first shown by Hohlfeld in 1824. His observations were extended in 1884 by Sir Oliver Lodge who continued the work and made a practical installation at a lead smelter in Scotland. Later, in 1905–06, this work was extended by Doctor Cottrell leading to the development of the electrical precipitation process for the separation of solids and liquids from gases.

Based upon "Electrical Equipment for Precipitation Service" (No. 32-77) presented at the A.I.E.E. summer convention, Cleveland, Ohio, June 20–24, 1932.

Briefly, this process functions in the following manner: Gases from which the materials are to be separated are passed through a chamber in which are 2 electrodes. A voltage is applied to these electrodes sufficient to cause corona discharge to take place. Electrons in this field acquire such high velocities that they break up the gas molecules into positive ions and additional electrons. These additional electrons move toward the positive electrode and are trapped by the solid particles which thereby obtain a negative charge. The charged particles are attracted to the positive pole and impinge upon it with considerable force. Here they release the trapped electrons and cling to the electrode surface by adhesion. For best results unidirectional current is used, and the discharge electrode is made negative and the collecting electrode positive.

Early applications were the cleaning of sulphuric acid mist and the cleaning of discharge gases from copper smelters to recover the non-ferrous metal particles which were being carried away in those gases. Later the field of application extended to cement, acid fumes, high temperature gas cleaning, detarring of combustible gases, and miscellaneous applications.

Extension of the field of application requires varying characteristics of power supply to the corona field. The electrical equipment usually consists of a transformer, mechanical rectifier, motor-generator, rectifier motor, switchboard, and accessories. This apparatus is all specially designed to withstand the unusual and difficult conditions of the precipitation circuit.

Fig. 1. A typical precipitator installation in a non-ferrous metallurgical industry

Electrodes for corona discharge consist of fine wires or rods hanging in the precipitator; the collecting electrodes are plates or pipes. Potentials used are between 20 and 75 kv, the actual voltage depending upon the design of the precipitator and the material to be treated. A rectifier connected

to the high voltage side of a step-up transformer is used to obtain the high potential unidirectional voltage. In one form of the mechanical rectifier the stator consists of 4 segments or shoes spaced 90 deg apart on a circle and mounted on fixed insulated arms. The rotor, which is driven by a small induction motor designed to operate at synchronous speed, consists of 2 insulated arms displaced 90 deg on the ends of which the contact tips are mounted and connected in series.

Disadvantages of the mechanical rectifiers may be summarized as follows:

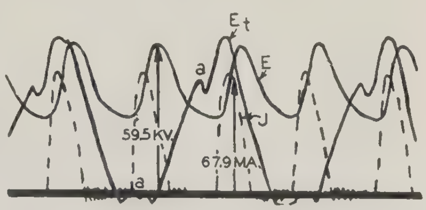
1. The continuous spark discharges cause oscillations and surges which create additional stresses in the transformer insulation.
2. The wave form is very irregular as shown by Fig. 2.
3. The contact tips and shoes commence wearing when the rectifier goes into service, continually decreasing the actual voltage at the precipitator. In addition a considerable amount of fixed resistance is necessary to assist in absorbing the energy of the surges caused by the spark discharge.
4. Equipment for suppressing radio interference is necessary.
5. Manual or automatic polarity control must be furnished, adding to the complexity of the control equipment.
6. It is noisy in operation.

Expansion of the precipitation field has created a growing demand for a rectifier unit that will furnish a more even wave shape and maintain the same precipitator voltage over an extended period of time. With the improvement in the radio art, and the inincreasing use of rectifiers in power applications, the obvious alternative is tube rectification. By this method a relatively smooth wave form of unidirectional current is obtained.

Scientific study of the electrostatic field and corona discharge will be greatly assisted by tube rectification, for this will permit assembling of data of the variables existing in precipitation applications due to varying temperatures and properties of the materials being treated.

In many applications the precipitator receives gases containing varying percentages of conducting and non-conducting particles. To meet these conditions, the current should be maintained constant; this will necessitate raising or lowering the voltage, utilizing to the maximum efficiency the fixed spacing of the electrodes in the precipitator.

Fig. 2. Wave form of voltage obtained from a mechanical rectifier



The load of the precipitator is unusual and unique. The negative lead from the rectifier is connected to the wire electrodes in the precipitator, a typical arrangement of which is shown diagrammatically in Fig. 3. The corona discharge from the negative wire electrodes ionizes the gases, thus reducing the normal dielectric insulation, thereby permitting the conveyance of the electron, by the particle, and increasing the normal capacity of the circuit.

Tube type rectifiers furnishing unidirectional supply to this unusual load will have the following advantages over mechanical rectifiers:

1. They require less space.
2. No surges in the circuit are caused by rectification.
3. The wave form supplied is regular.
4. The voltage remains constant throughout the operating life of the tube.
5. There is no radio interference from the rectifying equipment.
6. Polarity is controlled automatically.
7. Operation is very quiet.

The complete equipment for this application consists of transformer (including filament heating), tube rectifier, control, induction voltage regulator or tap changer, and sectionalizing switch for each compartment of the precipitator.

Because of the inherent characteristics of the precipitator, the transformers must withstand heavy surges or transient stresses. These surges, started by the flashover of the precipitator, would occasion concentrated voltage stresses in the coils adjacent to the line terminal if special arrangement were not made to avoid this condition. It has been found that the best protection is obtained by using a shielded transformer and a series resistance between the rectifier and the precipitator.

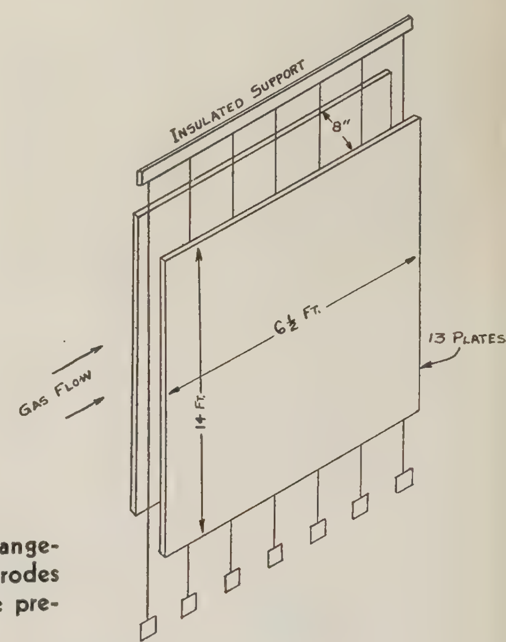


Fig. 3. Arrangement of electrodes in a plate type precipitator

It is necessary to vary the value of the unidirectional voltage supply depending on the type of precipitator, type of material being treated, and the load carried. As previously mentioned, this variation in voltage of about 50 to 100 per cent has been obtained by taps in the primary winding of the main transformer. There are 2 common methods for changing the taps; by bringing all taps to a special knife switch on the switchboard, or by using a tap changer under load. The precipitator voltage also may be varied by an induction regulator in the power supply line.

Rectifier tubes for this service must be of sturdy

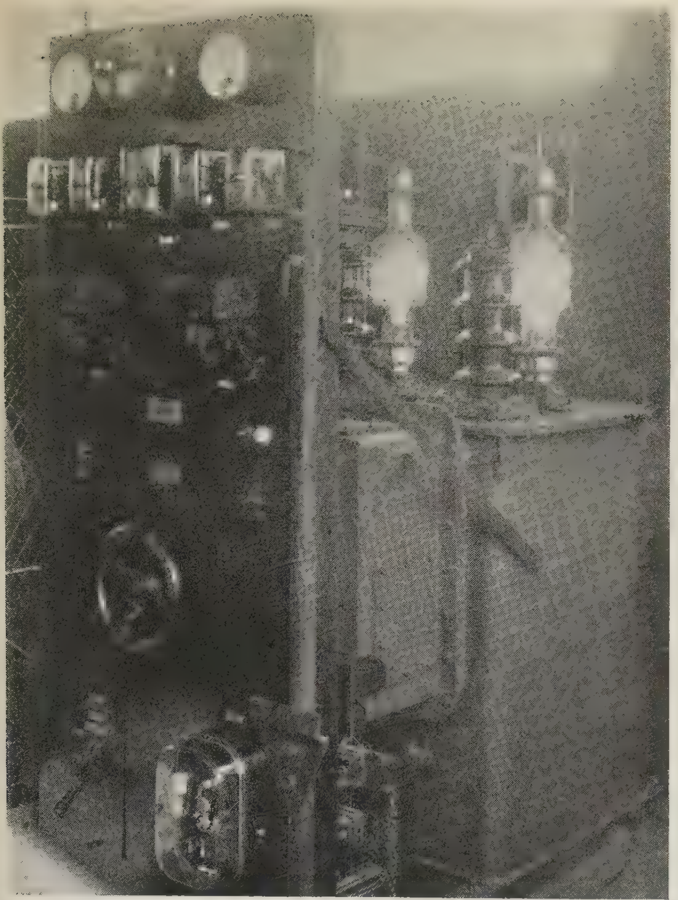


Fig. 4. A typical vacuum tube rectifier for precipitation service

construction to give sufficient length of life to make the application of tube rectifier units commercially practical. One requirement for long tube life is constant filament voltage. This usually is supplied by a small induction regulator or a specially designed static voltage regulator.

Tube rectifier circuits most frequently employed are:

1. Single-phase full-wave circuit employing 2 tubes (see Fig. 5).
2. Single-phase full-wave circuit using 4 tubes.
3. Three-phase half-wave circuit requiring 3 tubes.

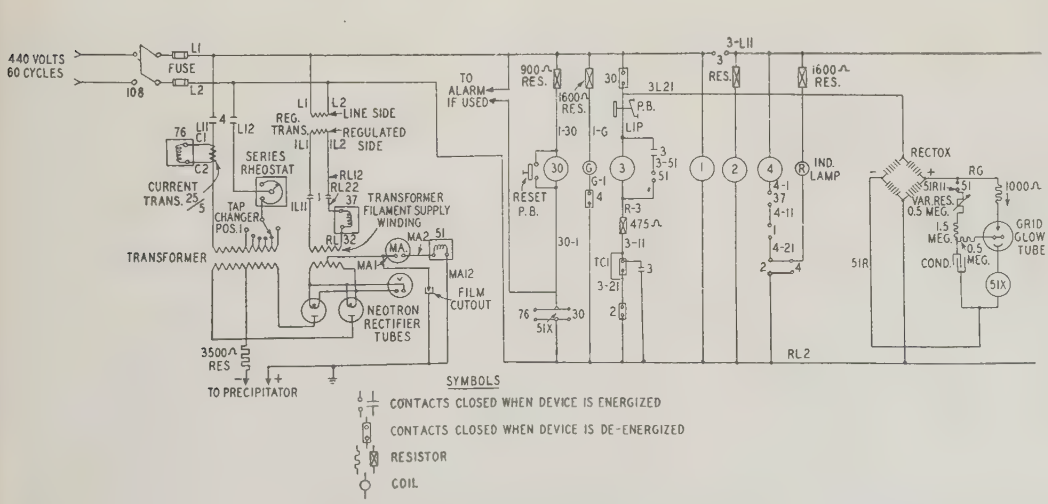
The theoretical maximum voltage that can be supplied in a single-phase circuit is 1.4 × rms value. However, the inverse potential may exceed this value. In the type of circuit under consideration where capacity is coupled with a high insulation resistance, the circuit is charged to maximum potential of 1.4 × E during the conducting period. When the tube is passing current this charge may not leak with sufficient rapidity so that a value nearly equal to 2 × 1.4E may be obtained across the tube on the inverse half-cycle. Such things must be kept in mind when selecting a tube with the proper peak inverse potential rating for this use.

In a single-phase full-wave circuit with 2 tubes (Fig. 4) when one tube is conducting the potential drop across it is comparatively low; hence the effective voltage across the other tube will be 2E, where E is the rms value obtained from one-half of the transformer winding. The maximum peak voltage therefore will be 2 × 1.4 or 2.8 × rms voltage from each half of the transformer.

The input capacity of the transformer for single-phase full-wave rectification is 1.1 times the output on the d-c side; thus where the d-c side is 10 kw the transformer would be 11 kva on the primary side since this is the measurable input.

Several installations of tube rectification have been made utilizing various combinations of transformer connection and number of tubes. One typical installation will be described as an example; this is illustrated in Fig. 4. Note the compactness of the unit assembly giving complete control of the apparatus. Added to the relays and meters needed in the control, there is mounted on the panel a contactor for the filament supply circuit and a similar contactor for the main supply to the primary of the transformer. A single handwheel controls both the tap changing equipment and the usual series resistance in the primary of the transformer. This arrangement gives a smooth voltage variation of approximately 50 per cent range on the high voltage side.

Single-phase full-wave rectification is used, consisting of a tube between each end of the transformer winding and the grounded positive side of the pre-



1 Filament supply contactor
2 Plate supply timing relay
4 Master relay
4 Plate supply contactor
108 Control power switch
30 Lockout relay (1M,1B) 440-volt coil
37 Filament undercurrent relay, 2–6 amp
51 High voltage d-c short-circuit protection relay, 0.5–1.5 amp
51X Auxiliary relay for 51
76 Primary overcurrent relay, 4–12 amp
G Green lamp, indicates "off"
R Red lamp, indicates "on"
TCI Interlock on tap changer, closed (not used) when on No. 1 position

Fig. 5. Schematic diagram of equipment illustrated in Fig. 4

cipitator. The center of the main winding is tapped for the negative high voltage lead to the precipitator circuit.

The control is relatively simple and is self-protective. The main feature is interlocking to insure the filaments being energized a few seconds before the plate of the tube. This prevents flashover which might result, because the full voltage applied is effective in speeding up the electrons before the filament has reached normal temperature. This bombardment results in overheating of the plate. In addition to this interlocking feature the only protection necessary is against short circuits, overloads, and loss of filament.

A diagram of the control scheme is shown in Fig. 5. Closing the knife switch energizes a time-delay relay which will complete the circuit for plate supply contactor 4. A relay with its coil in the primary of the filament transformer must first be energized otherwise contactor 4 could not be energized. When contactor 4 closes, the primary of the transformer is energized and voltage is applied to the tube the actual value of which depends on the setting of the tap changer. Rectification continues until the circuit is disconnected by the pushbutton or by the operation of protective relays. Relays to protect the tube from damage caused by overload or short circuit are connected in the control and function in the usual manner. A frequent cause of short circuit and overload is charged to the character of the gas. The acid content of the gas, gas temperature, changes in dust or fume content, have a marked effect on the dielectric characteristics of the materials, resulting in a change in load on the rectifier. Since the equipment should require no attendant, it is not desirable to take it out of service whenever any momentary overload occurs. Therefore if the circuit is made to reclose automatically a certain number of times, protection is obtained for the tube, and if the short circuit is only a momentary condition the equipment is permitted to continue in operation.

This protection is obtained on the installation by means of auxiliary relays which consist of a cold-cathode gas-filled electronic tube, a small condenser, associated resistors, and an auxiliary relay designated as $51X$. The tube breaks down or discharges only at a predetermined voltage across the condenser. The overcurrent relay being instantaneous, will close immediately in case of short circuits; one set of contacts in the grid circuit of the relay energizes the condenser circuit putting a certain potential on the condenser. This charge is not sufficient to cause the tube to discharge, but does not leak off for some time. After a short period the plate supply contactor is closed and if the short circuit is repeated the charge on the condenser is increased. The periodic opening and closing continues until the charge on the condenser reaches a sufficient value to energize the auxiliary relay $51X$ when the equipment is automatically locked out.

The tube rectifier installation permits consideration of the possibility of an automatic control of the precipitator unit. A proposed method is shown schematically in Fig. 6. This regulating equipment would consist of a constant-current regulating device, responding to the changes in the primary current of the transformer. These changes are caused by changes in the condition of the gas supplied to the precipitator, the object of the automatic regulator being to maintain current of a predetermined amount, calculated as the most efficiently operating value. To accomplish this, the voltage applied to the precipitator must be controlled by a single device.

In the circuit shown in Fig. 6, the primary relay as controlled by the current of the circuit will control the induction regulator, thereby raising or lowering the voltage as required. The voltage regulation by this arrangement is smooth and gives quick response, thereby maintaining a constant current to the precipitator regardless of changes in the characteristics of the gases.

1 Master relay
1X Filament supply contactor
2 Timing relay
4 Main contactor
9 Control contactor
30 Lockout relay
30X Auxiliary lockout relay (hand reset)
37 Undercurrent relay
51 Overload relay
57 Constant current regulator (primary relay)
R "Raise" coil of secondary relay
L "Lower" coil of secondary relay
70R Interlock on induction regulator, closed at lower limit of travel

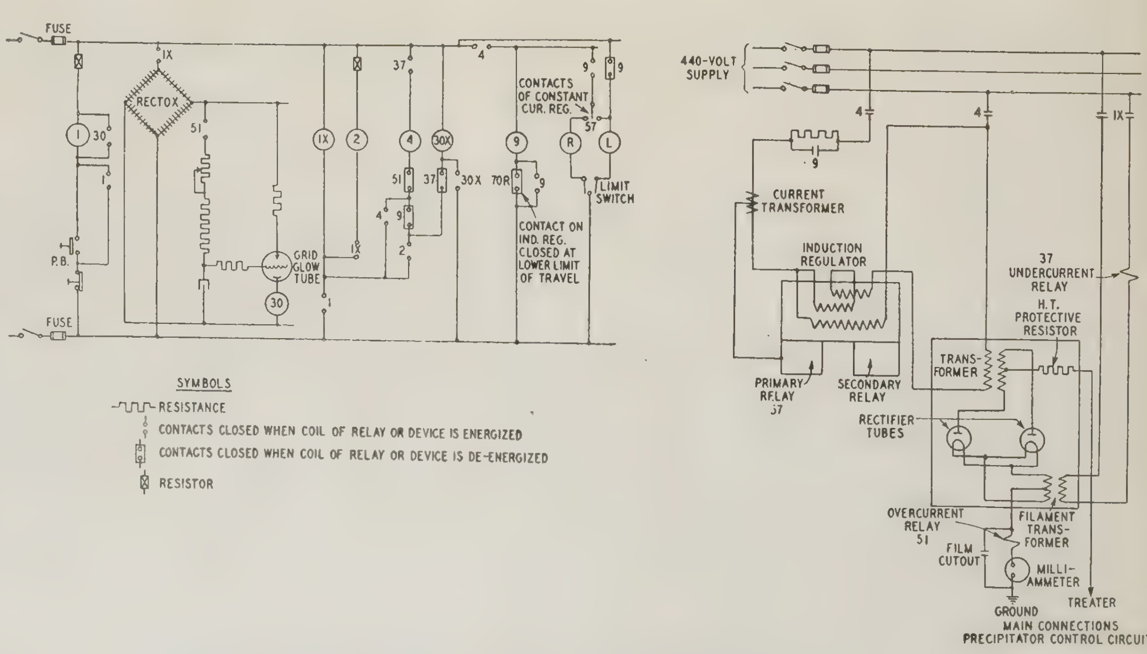


Fig. 6. Diagram of control for full automatic precipitation equipment

Abstracts

Of Papers to Be Presented at the Schenectady District Meeting

INTERPRETIVE abstracts of all papers scheduled for presentation at the A.I.E.E. Schenectady District meeting (May 10–12, 1933) are published herewith, excepting only: (1) those papers published in this or the preceding issue; and (2) those papers which, at the time of going to press for this issue, have not yet been made available by the authors. Members vitally interested and wishing to obtain a pamphlet copy of any paper available in that form may do so by writing to the A.I.E.E. Order Dept., 33 West 39th Street, New York, N. Y., stating title, author, and publication number of each paper desired.

The Electrical Characteristics of Impregnated Cable Papers

By
C. L. Dawes[1]
P. H. Humphries[2]

IN CONNECTION with the investigation of ionization in impregnated paper insulated cables conducted at The Harvard Engineering School under auspices of the impregnated paper cable research committee of the National Electric Light Association, it was found necessary to determine over a considerable range of voltage gradient, temperature, and frequency, the electrical characteristics of cable paper impregnated with different cable oils and compounds. The impregnation was conducted under almost ideal laboratory conditions so that little if any gas was occluded. When the results of the measurements were rationalized and analyzed, it was found that to a remarkable degree they all conformed to the same general laws. These laws and the analyses of the electrical characteristics into components may appear to be only empirical. However, they are results of some fundamental causes, involving probably molecular and intramolecular reactions. Therefore, aside from any value which the results presented may have as engineering data, they may at some time be of value in confirming or in disproving some more fundamental theories of dielectrics. Moreover, it is found that actual cables when impregnated so thoroughly that they manifest no appreciable ionization, have electrical characteristics comparable to those obtained with these samples impregnated under almost ideal conditions. The conclusions presented in this paper are as follows:

1. An abrupt change in the slope of the cooling curves of some cable compounds occurs in the neighborhood of 50 deg C; this may indicate changes in the molecular structure.

2. It appears to be a general law that the power loss in cable compounds varies as a constant exponential power of the voltage gradient, the exponent usually being 2 at room temperature; at higher temperatures it may be greater or less than 2.

3. The power factor characteristics of cable compounds are exponential functions of the voltage gradient, the exponent being related to that for the power characteristics.

4. The power-frequency characteristics are essentially linear, having a positive intercept at zero frequency.

5. The power factor-frequency characteristics are essentially rectangular hyperbolas.

6. The equivalent series resistivity-voltage gradient characteristic is the same type of function as the power factor-voltage gradient characteristic.

7. The equivalent parallel conductivity-voltage gradient characteristic is the same type of function as the power factor-voltage gradient characteristic.

8. The power-temperature characteristics for constant frequency and constant voltage gradient appear to consist of 2 terms, each of which is a constant-exponential function of the temperature. **(A.I.E.E. paper No. 33-58)**

1. Harvard University, Cambridge, Mass.
2. Tulane University, New Orleans, La.

Loss Characteristics of Silicon Steel at 60 Cycles With D-C Excitation

By
R. F. Edgar[3]

CORE-LOSS and excitation characteristics of sheet steel subjected to combined alternating and direct magnetic fields, have been subjects of investigation for the past 20 years. Such combined fields occur in many types of electrical apparatus. This paper presents the results of a series of 60-cycle core-loss and excitation tests with superposed d-c excitation, which recently were made on silicon sheet steel.

Both the alternating and the direct components of flux density (referring respectively to half the amplitude of pulsation, and to the average over a complete cycle) covered wide ranges. That of the former extended to 18,000 gausses (116.1 kilolines per sq in.) and that of the latter to 15,600 gausses (100 kilolines per sq in.). Corrections were made for distortion of the voltage wave-form at high flux densities.

Results show that for any given alternating flux density above a certain value, which may be called the "critical value, the hysteresis loss decreases as d-c excitation is superposed; for any alternating flux density below that value, it tends to increase gradually to a maximum, and then to decrease. The critical value was found to be in the range 13,200 to 13,800 gausses (85–89 kilolines per sq in.).

In all cases the effect of superposed d-c excitation was to increase the a-c excitation required to maintain a constant amplitude of alternating flux density. The d-c excitation required to maintain a constant direct component of flux density, in the low or moderate density range, was decreased by a small superposed a-c excitation, and then increased as the a-c excitation was raised. For high direct flux density, no decrease in d-c excitation was obtained. **(A.I.E.E. paper No. 33-54)**

Design of Resistance Welder Transformers

By
H. E. Stoddard[5]

DUE TO increased production demands, the speed at which resistance welders operate has been stepped up as much as 4 to 5 times during the last few years. This has been made possible in a large degree, by the development of new switching mechanisms that will allow a current dwell of a fraction of a cycle on 60-cycles.

This increased speed of welding has made it necessary to study very carefully the design of the transformer and the shape and spacing of the secondary circuits, especially the cooling and protection of these parts. It has been necessary also to pay more attention to multi-transformer welders, where several transformers are used either for the purpose of distributing the secondary current to better advantage, or for the purpose of balancing the welder load on multiphase circuits.

In this paper, the various factors which must be considered in the design of transformers for resistance welders are considered. The relative transformer capacities for various types of resistance welders are given. The various types of transformer secondaries are discussed, including flexibility, space factors, cooling, eddy currents, etc. Methods of voltage control are outlined. Various mechanical problems are discussed, and multiple transformers are considered. **(A.I.E.E. paper No. 33-60)**

3. General Electric Company, Schenectady, N. Y.
4. General Electric Company, West Lynn, Mass.
5. Thomson-Gibb Electric Welding Company, Lynn, Mass.

Radio Aids to Air Navigation

By
C. F. Green[3]
H. I. Becker[3]

(See p. 307–13 this issue.)

Reactive and Fictitious Power

By
V. G. Smith[9]

(See ELECTRICAL ENGINEERING for April 1933, p. 268–70.)

Reactive Power and Power Factor

By
W. V. Lyon[10]

GENERAL definitions exist for potential, current, and active and reactive power, that are independent of wave form and of circuit conditions. In order to use these quantities in circuit analysis when there are harmonics present, it is necessary to know their individual harmonic components. By definition, single-phase power factor is a blanket factor which covers and so disregards any deviation in wave form from the sinusoidal. Thus it is not a quantity that can be used in circuit analysis when there are harmonics present. If polyphase power factor is defined as the ratio of the power to the magnitude of the vector volt-amperes it is likewise a useless quantity in circuit analysis if there are harmonics present. Furthermore, this definition of polyphase power factor makes it a derived quantity which depends upon the active and reactive power. Even when there are no harmonics present so that power factor may be legitimately used, the circuit calculations are usually simpler if the loads are determined by their active and reactive powers rather than by their power factors. That is, as far as circuit analysis is concerned, power factor is a quantity whose retirement need scarcely be noted.

There is, however, another and important use for power factor; namely, when specifying the character of power loads from a commercial standpoint, that is, when writing specifications or power rates. In that case it does not seem necessary that power factor should have a rigorous scientific definition but that it be considered as a purely commercial quantity and defined accordingly. It may be that the present definitions of single-phase and polyphase power factor are adequate. However, before the definition is written we should decide upon the status of power factor; whether it is to be classed as a scientific quantity like power, for example, or as a commercial quantity like load factor. In making this decision we should frankly recognize that if it is to be considered as a scientific quantity which is useful in circuit analysis, both the single-phase and polyphase definitions must be rewritten. If this is done, the resulting quantity will not, on the whole, be as useful in circuit calculations as the concept of reactive power. And furthermore, in this case the power factor will not be the useful commercial quantity which now appears in specifications and power contracts.

Reactive power is due to some physical characteristic of the circuit which causes a phase displacement between the potential across the circuit and the current in it. In general, however, reactive power cannot be said to equal any one definite physical quantity. The best physical concept that we have is based upon the mean value of the stored energy, but in determining this mean value the energy stored in an inductance must be counted of opposite sign to that stored in a condenser. Furthermore this concept is valid only when the circuit is linear and the impressed potentials are of a single frequency. Any concept based wholly upon the instantaneous value of the stored energy or of the time rate of change of the stored energy will probably lead to great confusion. **(A.I.E.E. paper No. 33-55)**

9. University of Toronto, Ontario, Canada
10. Massachusetts Institute of Technology, Cambridge, Mass

Notes on the Measurement of Reactive Volt-Amperes

By
W. H. Pratt[4]

THE CHARACTER of the quantity known as reactive volt-amperes is first discussed and its dependence upon the assumption of a definite type of periodicity is brought out, this in contrast to certain other a-c quantities. It is pointed out that on account of the rather complicated relation that it bears to the flow of energy in an electric circuit, serious difficulties are met in its measurement except in the simpler conditions of balanced voltages, in a polyphase circuit, and sinusoidal waves. Two procedures are outlined which though they are not premised on balanced voltages have frequency and wave form limitations.

In the latter part of the paper, the relation of the quantity of energy that surges in an a-c circuit in which there is energy storage, to the average flow of energy is considered, and advantages of this conception as a basis for rates are indicated.

A table of the relative magnitudes of the quantities under discussion is given, and it is suggested that average positive power could very well form the basis for rate schedules. It would introduce substantially no penalty for power factor for values of the latter above 90 per cent, only slight penalty at 80 per cent, about 22 per cent at 50 per cent power factor, and at zero power factor the rate would be based on a quantity just under one-third of the volt-amperes. At 60 deg phase displacement, for each 100 units of net power consumed, 122 units are delivered and 22 returned, yet the reactive volt-amperes are 173, the volt-amperes 200.

Average positive power may be measured directly or by the arithmetic addition of average negative power to average power. If evaluated by the latter method, comparatively rough measurements of the negative contribution would suffice unless the power factor is habitually low; especially is this statement true if the power factor is generally fairly high. Similar statements may be made in regard to average positive energy flow, average energy flow and average negative energy flow. Whatever the character of unbalance or of wave form the measurement procedure outlined leads to measurable quantities of an unambiguous nature that seem well suited to commercial use. Negative power in its relations to positive power and average power represents a direct comparison of the actual activities in the circuit.

Finally, it is pointed out that reactive volt-amperes is the measure of a quantity that does not appear in the circuit as such but is only the coefficient of an arbitrarily chosen component of power pulsation and has dimensions and magnitude such that the equation $W^2 + S^2 = E^2I^2$ is satisfied. [S = reactive volt-amperes. For complex waves $\Sigma\,(W_1^2 + W_3^2 + \ldots + S_1^2 + S_3^2 + \ldots) = E^2I^2$.] It is a sort of complementary quantity useful in calculation. It connotes the defect that exists between actual and ideal utilization of the quantities of current and voltage appearing in the circuit.

There is no intention to disparage the use of reactive volt-ampere measurements as a means of determining kilovolt-amperes in the measurement of demand. This last quantity (kva) undoubtedly has its field of usefulness. **(A.I.E.E. paper No. 33-61)**

Power, Reactive Volt-Amperes, Power Factor

By
C. L. Fortescue[11]

(See p. 319–23 this issue.)

Operating Aspects of Reactive Power

By
J. Allen Johnson[12]

(See ELECTRICAL ENGINEERING for April 1933, p. 262–8.)

11. Westinghouse Electric and Manufacturing Company, East-Pittsburgh, Pa.
12. Buffalo, Niagara & Eastern Power Company, Buffalo, N. Y.

News

Of Institute and Related Activities

Summer Convention to Coincide With Engineers' Week at Chicago

THE 49th annual summer convention of the A.I.E.E., to be held in Chicago, Ill., June 26–30, 1933, concurrent with "A Century of Progress International Exposition," offers unusually attractive features. The summer convention committee has arranged a number of joint activities, entertainment features, trips and sports which, combined with an excellent technical program, assure a pleasurable and profitable week. Convention headquarters will be at the Edgewater Beach Hotel on the shore of Lake Michigan.

Aside from the architectural splendor and international features of the Century of Progress Exposition, the central station exhibit alone will have an unusual appeal to all who are engaged in the electrical industry. Dioramas and working models will portray every conceivable phase of the light and power industry from the source of generation through the stages of transmission and distribution to modern rural, commercial, and domestic utilization. The illuminating displays and modern household uses of electrical energy will be of particular interest to the women.

Joint Meetings

Tuesday evening, June 27, there will be a meeting on industrial developments of the century, under the auspices of Section M of the American Association for the Advancement of Science. The meeting will take place in the grand ballroom of the Palmer House and Dr. A. P. M. Fleming (M'14 and local honorary secretary) Manchester, England, will be the principal speaker.

Wednesday, June 28, will be known as Engineers' Day with a number of engineering societies participating in joint activities. Present plans call for a general assembly at the Century of Progress grounds in front of the Hall of Science at 10:30 a.m. A series of short speeches will be delivered by prominent engineers, some from without the United States. The afternoon will be left free for trips and an inspection of the exposition. In the evening a joint dinner will be held at the Stevens Hotel. Arrangements which are being made plan for 1 or 2 prominent speakers, and for dancing later in the evening. The admission will be $3 per ticket. It is expected that reservations and tickets for the Tuesday evening meetas well as tickets for Engineers' Day, will be on sale at the registration desks of the various societies.

Thursday afternoon, June 29, there will be a joint meeting with the hydraulic division of American Society of Civil Engineers, and the power division of The American Society of Mechanical Engineers. A résumé of the engineering reports on the St. Lawrence waterway development will be presented and Daniel W. Mead, consulting engineer, and professor at the university of Wisonsin, will be one of the principal speakers. It is also planned to have the Canadian point of view presented.

Friday afternoon and evening, June 30, a joint meeting with the Econometric Society, the A.S.M.E., and the American Society for Testing Materials will present "Some Fundamental Problems of Mutual Interest to Scientific Economists and Engineers." Among the well-known speakers are 2 who are prominent Institute members, namely, Dr. A. P. M. Fleming, and Dr. F. B. Jewett (A'03, F'12, and past-president).

Technical Sessions

In addition to the foregoing meetings, 6 technical sessions will be held and a number of papers will present noteworthy advances in the various electrical fields. The protective devices session will deal with relays, circuit breakers, and lightning arresters. The power transmission and distribution session will have 4 papers which will present valuable data in the field of cable research. Another session will deal with the latest developments and technique in the field of intruments and measurements. Communication and power generation are subjects which will be presented in another. Two other sessions will treat subjects in the fields of electrical machinery, electric welding, electrophysics, and research. The technical program should leave little to be desired for those who are theoretically in-

Edgewater Beach Hotel on the shores of Lake Michigan, Chicago, Ill., will be the headquarters for the Institute's summer convention. The main building and addition is shown here with the recreational facilities which include a 9-hole mashie-putting golf course, tennis courts which may be lighted for night play, private bathing beach, and children's playgrounds

One of the 2 children's playgrounds at the Edgewater Beach Hotel, Chicago, that will absorb the attention of many members of the families of those attending the Institute's summer convention

clined as well as those who are interested in design and operation.

Trips

Because of the great interest in the Century of Progress Exposition there are no prearranged trips except to the exposition grounds. For any of the delegates interested, the committee will arrange inspection trips, in small groups, to various points of technical interest around Chicago, such as generating stations, substations, high capacity underground installations, automatic telephone exchanges, etc. The committee also can arrange special facilities for transportation of groups between convention headquarters and the exposition grounds, including direct speedboat trips.

On Wednesday, the day of the joint meeting, after the general assembly in the morning, there will be conducted trips to some of the exhibits which are of particular interest to electrical engineers. The details of these trips have not been arranged as yet.

Any one wishing to visit any other points of interest should get in touch with the representative of the trips committee at the registration desk.

Women's Entertainment

The women's entertainment committee has arranged for a circle tour of the parks and boulevards of the city on Tuesday afternoon, for which a charge of 75 cents will be made. For those who care to take this trip a complimentary luncheon will be given at one of the clubs in Chicago through the courtesy of one of the local members of the Institute.

Committee members will also be on hand to give the visiting women advice and information on shopping tours. It is possible there will be special trips for the women to the exposition grounds.

Sports

The sports committee is planning events in golf, tennis, and ping pong for the convention. The golf events will be held at the Westmoreland Country Club, June 26–29. Westmoreland is a beautiful, rolling course of championship caliber, located northwest of Evanston, Ill., a distance of approximately 11 miles from the Edgewater Beach Hotel.

Private bathing beach of the Edgewater Beach Hotel, Chicago

The qualifying round for the Mershon Trophy, a match play tournament on a handicap basis, will be held on Monday, June 26, the 16 lowest net scores to qualify for match play. Matches will be played on Tuesday and Wednesday afternoon with the semi-finals and finals on Thursday morning and afternoon. The Monday scores will also apply as the first round on the Lee Trophy, which is a 36-hole low net score tournament. The second round is to be played on Tuesday afternoon. It is also planned to have a low net, low gross, and blind bogey event on Monday, and a low gross and low net event on Tuesday. Arrangements are also being made to secure playing privileges on a number of the best courses in the Chicago district.

The annual tennis tournament for the Mershon Trophy, a men's single event, will be held on the courts of the Edgewater Beach Hotel. Matches will start Monday afternoon, June 26. There will be no charge for the use of the courts.

The ping pong tournament will be held at the Edgewater Beach Hotel, starting Monday afternoon, June 26. Prizes will be awarded for all of the sports events.

Hotel and Railroad Rates

In the accompanying table are given the rates of the headquarters hotel, the Edgewater Beach, and several other hotels in the vicinity. Reservations should be made by writing directly to the hotel preferred.

Hotel	Single Room With Bath	Double Room With Bath	Distance From Headquarters Hotel
Edgewater Beach	$5.00 (Special convention rates)	$7.00	Convention headquarters
Rogers Park	$3.00	$5.00	$1^3/_4$ miles
Sheridan Plaza	$2.50	$4.00	$1^1/_4$ miles
Sovereign	$3.00 to $5.00	$4.00 to $6.00	$1^1/_4$ miles

Especially low railroad rates for the entire period of the exposition will be in effect, but, as they differ considerably for different starting points and the duration of the stopover period, members should consult their local passenger agents for excursion rates to the exposition.

Program

Abstracts of papers to be presented at the summer convention are scheduled for publication in the June 1933 issue of Electrical Engineering, as they were not available in sufficient numbers for inclusion in this issue.

Monday, June 26

9:00 a.m.—Registration

10:00 a.m.—Opening Session

Annual business meeting of the Institute

Annual report of the board of directors (in abstract), H. H. Henline, *national secretary*

Report of tellers' committee on election of officers; introduction of and response from president-elect

Presentation of prizes for papers

Lamme Medal presentation

President's address, by H. P. Charlesworth

2:00 p.m.—Conference of Officers, Delegates, and Members

Tuesday, June 27

9:30 a.m.—(A) Protective Devices

Testing of High Speed Distance Relays, E. E. George, and W. R. Brownlee, Tennessee Electric Power Co.

Relaying of High Voltage Interconnection, H. P. Sleeper, Public Service Electric & Gas Co.

Arc Extinction Phenomena in High Voltage Circuit Breakers Studied With a Cathode Ray Oscillograph, R. C. Van Sickle and W. E. Berkey, Westinghouse Electric & Mfg. Co.

Interrupting Capacity Tests on Circuit Breakers, R. M. Spurck and W. F. Skeats, General Electric Co.

Present Practice on Installation and Performance of High Voltage Lightning Arresters for 11 Kv and Above, A.I.E.E. and N.E.L.A. Subcommittees on Lightning Arresters.

9:30 a.m.—(B) Instruments and Measurements

* Compensating Metering in Theory and Practice, G. B. Schleicher, Philadelphia Electric Co.

* Classification of Bridge Methods of Measuring Impedances, J. G. Ferguson, Bell Telephone Laboratories, Inc.

* Better Instrument Springs, R. W. Carson, Westinghouse Electric & Mfg. Co.

* Recent Developments in Sound Measurement, H. B. Marvin, General Electric Co.

* A Portable Oscillograph With Unique Features, K. A. Oplinger, Westinghouse Electric & Mfg. Co.

2:00 p.m.—Conference of Officers, Delegates, and Members

Evening—Joint meeting under the auspices of Section M of the American Association for the Advancement of Science

Wednesday, June 28, Engineers' Day

10:30 a.m.—Joint meeting with a number of engineering societies convenes at the Century of Progress Grounds in front of the Hall of Science

Evening—Dinner at the Stevens Hotel, followed by dancing—Admission $3

* These papers are under consideration for presentation at the summer convention, but up to date of going to press have not been officially placed upon the program.

Notice of Annual Meeting

The Annual meeting of the American Institute of Electrical Engineers will be held in the Edgewater Beach Hotel, Chicago, Ill., at 10 a.m. on Monday, June 26, 1933. This will constitute one session of the annual summer convention which is to be held this year in Chicago, June 26–30.

At this meeting the annual report of the board of directors and the report of the committee of tellers concerning the ballots cast for the recent election of officers will be presented.

Such other business, if any, as properly may come before the annual business meeting may be considered.

(Signed) H. H. Henline
National Secretary

Thursday, June 29

9:30 a.m.—(C) Power Transmission and Distribution

The Expulsion Protective Gap, K. B. McEachron, General Electric Co., I. W. Gross, American Gas and Electric Co., and H. L. Melvin, Electric Bond and Share Co.

The "De-Ion" Flashover Protector and Its Application to Transmission Lines, A. M. Opsahl and J. J. Torok, Westinghouse Electric & Mfg. Co.

The Life of Impregnated Paper, J. B. Whitehead, The Johns Hopkins University.

Accelerated Aging Tests on High Voltage Cable, and Their Correlation With Service Records, D. W. Roper, Commonwealth Edison Co.

The Effect of High Oil Pressure Upon the Electrical Strength of Cable Insulation, J. A. Scott, General Electric Co.

A New Method of Investigating Cable Deterioration and Its Application to Service Aged Cable, K. S. Wyatt, E. W. Spring, and C. H. Fellows, The Detroit Edison Co.

9:30 a.m.—(D) Communication and Power Generation

* Telephone Carrier in Cable, A. B. Clark, American Telephone and Telegraph Co., and B. W. Kendall, Bell Telephone Laboratories, Inc.

* Precision Timing in the Athletic and Sport Field, C. H. Fetter, Electrical Research Products, and H. M. Stoller, Bell Telephone Laboratories, Inc.

Design Features of the Port Washington Power Plant, G. G. Post, The Milwaukee Electric Railway and Light Co.

The Beauharnois Development of the Soulanges Section of the St. Lawrence River, W. S. Lee, W. S. Lee Engineering Corp.

2:00 p.m.—Joint meeting with A.S.C.E. and A.S.M.E. on development of the St. Lawrence River

Friday, June 30

9:30 a.m.—Electrical Machinery and Welding

* Transient Torques in Synchronous Machines, M. Stone and L. A. Kilgore, Westinghouse Electric & Mfg. Co.

* The Effect of Transient Voltage Protective Device on Stresses in Power Transformers, K. K. Palueff and J. H. Hagenguth, General Electric Co.

Improvements in Mercury Arc Rectifiers, J. H. Cox, Westinghouse Electric & Mfg. Co.

Current and Voltage Wave Shape of Mercury Arc Rectifiers, H. D. Brown and J. J. Smith, General Electric Co.

* Arc Stability With D. D. Welding Generators, L. R. Ludwig and D. Silverman, Westinghouse Electric & Mfg. Co.

* Construction Features of Special Resistance Welding Machines, C. L. Pfeiffer, Western Electric Co.

9:30 a.m.—(E) Electrophysics and Related Subjects

Progress in Three-Circuit Theory, A. Boyajian, General Electric Co.

The Polarity Factor in the Kindling of Electric Impulse Sparkover Based on Lichtenberg Figures, C. E. Magnusson, University of Washington

* Obtaining Comfort Conditions by Means of Controlled Radiation From Electrically Heated Walls, L. S. Schad, Westinghouse Electric & Mfg. Co.

* Probe Measurements and Potential Distribution in Copper A-C Arcs, W. G. Dow, S. S. Attwood, and G. S. Timoshenko, University of Michigan.

Afternoon and Evening—Joint meeting with the Econometric Society, A.S.M.E., and A.S.T.M.

Rules on Presenting and Discussing Papers

At the technical sessions papers will be presented in abstract, 10 min. being allowed for each paper unless otherwise arranged or the presiding officer meets with the authors preceding the session to arrange the order of presentation and allotment of time for papers and discussion.

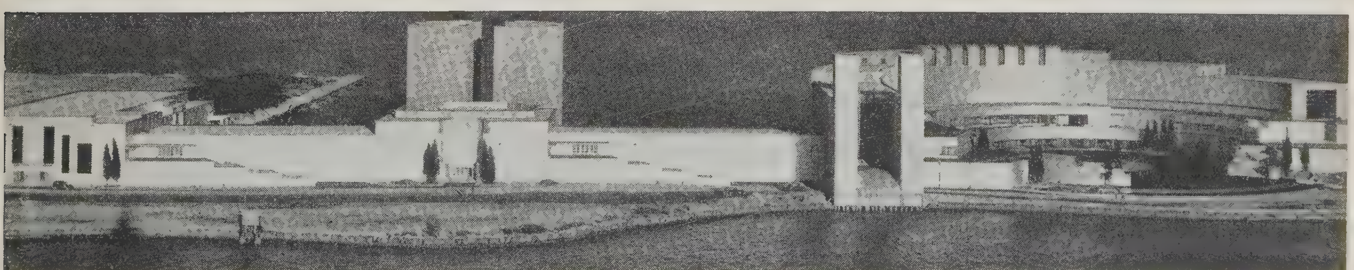
Any member is free to discuss any paper when the meeting is thrown open for general discussion. Usually 5 min. are allowed each discusser. When a member signifies a desire to discuss papers on other subjects or groups, he shall be permitted a 5-min. period for each subject or group.

It is preferable that a member who wishes to discuss a paper give his name beforehand to the presiding officer of the session at which the paper is to be presented. Copies of discussion prepared in advance should be left with the presiding officer. Each discusser is to step to the front of the room and announce, so that all may hear, his name and professional affiliations.

Discussions at the technical sessions are not reported. To be considered for publication, discussions should be written and mailed to the A.I.E.E. Editorial Department, 33 West 39th Street, New York, N. Y., on or before July 14, 1933.

Committees

The general convention committee for the 1933 summer convention consists of the following members: L. A. Ferguson, *honorary chairman;* H. B. Gear, *chairman;* T. G. LeClair, *secretary-treasurer;* and K. A. Auty, W. H. Harrison, P. B. Juhnke, J. E. Kearns, W. O. Kurtz, and L. R. Mapes. The chairmen of the various subcommittees working with the general convention committee are as follows: meetings and papers, Burke Smith; inspection trips, E. C. Williams; entertainment, H. W. Eales; sports, J. H. Irwin; transportation, R. I. Parker; hotels and registration, J. E. Kearns; publicity, F. R. Innes; finance, F. H. Lane, and women's entertainment, Mrs. C. W. PenDell.



Telephone and telegraph communication exhibit of the "Century of Progress" Chicago 1933 exposition, will be housed in the long unit in the center above. The semicircular unit on the right will house exhibits for the generation, distribution, and utilization of electricity. On the extreme left is the Hall of Social Science. These and many other buildings will be inspected by those attending the Institute's summer convention in Chicago

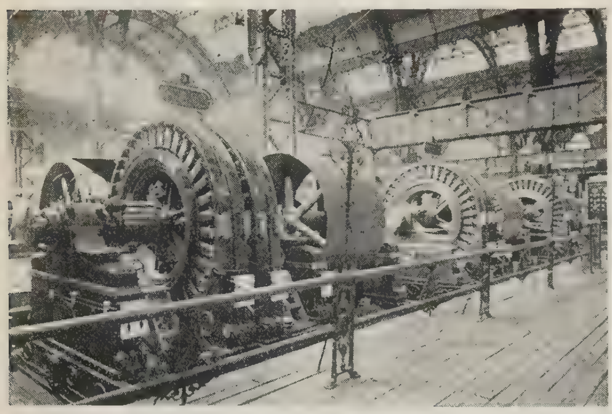
1893—The Columbian Exposition, Chicago World's Fair

Westinghouse photo

Interior of the electricity building at the Columbian Exposition, Chicago World's Fair of 1893. The use of electricity for lighting was one of the most spectacular features of this exposition

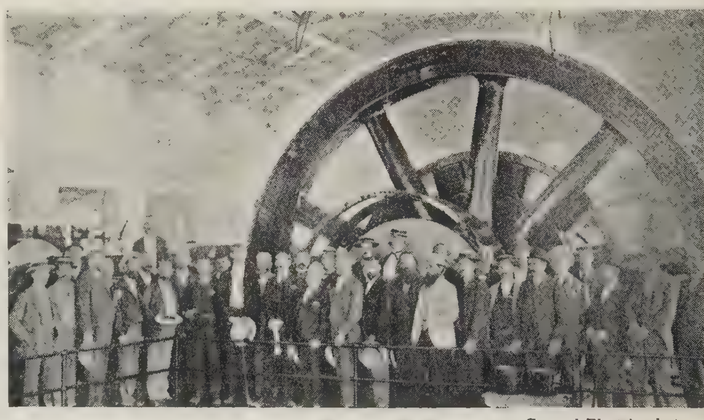
Westinghouse photo

The World's Fair in Chicago in 1893 attracted tremendous crowds and had a strong influence on social, economic, and industrial practices for the following decade. The forthcoming Century of Progress Exposition will probably leave a similar mark upon the American people



Westinghouse photo

Three of the 12 1,000-hp 2-phase generators which supplied power to the Chicago World's Fair of 40 years ago



General Electric photo

Delegates of the Association of Edison Illuminating Companies visit the intramural power house at the World's Fair in Chicago, 1893

With the Institute's annual summer convention scheduled for Chicago during the fourth week of the 1933 international exposition, there is available to Institute members a most unusual opportunity for an interesting and a highly profitable vacation trip. Convention details have been outlined on preceding pages; a few of the many exposition features are mentioned briefly on these facing pages, the tremendous scope of the exposition program precluding even a comprehensive outline here.

Science and Industry Exhibits

From a professional point of view, the applied science and industry exhibits with their many scale models, undoubtedly will appeal to engineers. These are arranged in 6 groups, as follows:

1. The travel and transport group includes exhibits of transportation by rail, highway, waterway, and in the air, together with exhibits by the associated industries such as the manufacturers of railway and automotive equipment and supplies.

2. The electrical group includes exhibits of the manufacture of electrical machines, the generation, distribution, and utilization of electric power, applications of electricity in communication, and the utilization of electricity in radio transmission.

3. The agricultural group includes exhibits of food products, farm machinery and equipment, dairy products and poultry.

4. The medical and chemical group includes exhibits from manufacturers of articles which serve the medical professions and from the closely associated manufacturers of chemicals. These exhibits will be shown in the Hall of Science in proximity to the scientific exhibits in medicine and under the same roof with the other basic science exhibits.

5. The general exhibits group includes the exhibits of the mineral industries and industrial engineering related thereto, and the historical and process exhibits of the graphic and industrial art industries.

6. The home and industrial arts group includes applications of any industry in the home and municipality. Here new materials and methods of construction, the genius of interior decorators and home planners, the work of municipal and sanitary engineers and the products of those manufacturers who featured home furnishings and equipment will be on view.

To members of the Institute attending the 49th annual summer convention in Chicago, June 26–30, the electrical group will doubtless be of the greatest interest. However, the Hall of Science located on the mainland directly across the lagoon from the electrical buildings, also will house many exhibits of special interest to technical men. The travel and transport building, too, will be a feature, with its 125-ft dome suspended by cables.

The site of the exposition is within walking distance of the heart of Chicago, the grounds extending along the shore of Lake Michigan from Twelfth Place to 39th Street, and including Northerly Island, separated from the shore by the lagoon. It is on this island that the electrical group is located.

The Columbian Exposition held in Chi-

cago in 1893 was distinguished by many unusual features, but the greatest impression on the visitors to this previous exposition was made by the applications of electricity, principally in its revolutionary method of lighting and the curious machines employed in its production. In the 40 years since the Columbian Exposition we have become used to seeing gigantic spectacles and observing unusual things. However, the many recent developments in the field of electricity will make a striking impression on the visitors to the 1933 Exposition as well, and many engineers who pride themselves on knowing the latest developments in their fields, will be surprised by the unusual applications of these developments which are being incorporated in the many exhibits.

The central station exhibit in the main electrical building will be concerned primarily with the utilization of electricity. However, a feature of this exhibit will be the diorama, some 85 ft in length, depicting the production and distribution of electricity. A steam-electric generating station and a high-head and a low-head hydroelectric plant will be depicted, with transmission lines and substations linking them into an interconnected system from which are supplied the homes, businesses, and industries of the city and country. The diorama will be animated with lights and flowing water, spinning turbines and all the movement of busy life.

Separate from the diorama will be utilization display, grouped in 6 main divisions to show the uses of electricity in commercial buildings, schools and colleges, hospitals and public health institutions, various industries, the home, and on the farm. The greater part of these displays will consist of actual equipment in full size installations.

Spectacular Lighting Effects

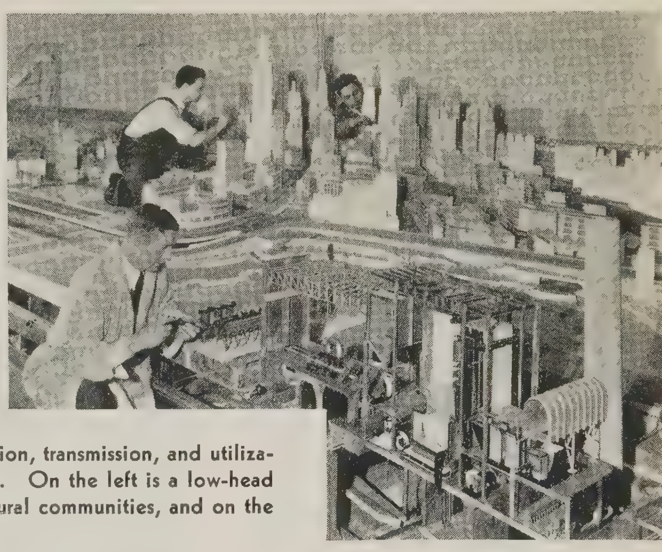
Spectacular lighting effects in the grounds and on the exterior surfaces of many of the buildings will feature the exposition. The general illumination of the grounds will introduce new methods of outdoor lighting which produce a very pleasing effect. The principal manufacturers of electrical equipment are working jointly on the development of this immense lighting project. Throughout the many buildings of the exposition, too, will be found unusual effects in indoor lighting produced by modern illumination.

It has been estimated that more than 2,100 kw of electric energy will be required to light the thousands of light sources installed outdoors. Electric lamps of every description—arc, incandescent, and gaseous tubes—will be used. More than 15,000 incandescent lamps, ranging in size from 10 to 3,000 watts, will be used for the exterior illumination alone. It is possible only to guess the number that will be installed within the exposition buildings and concessions.

For building illumination, a thousand 1,000-watt floodlights and 2,200 200-watt projectors will be used. Supplementing the effects of these lights, which will be directed only on the exteriors of buildings, a total of 375 combination street and flood-lighting standards, 25 different designs of which have been prepared for the exposition, will brighten the roadways and smaller structures.

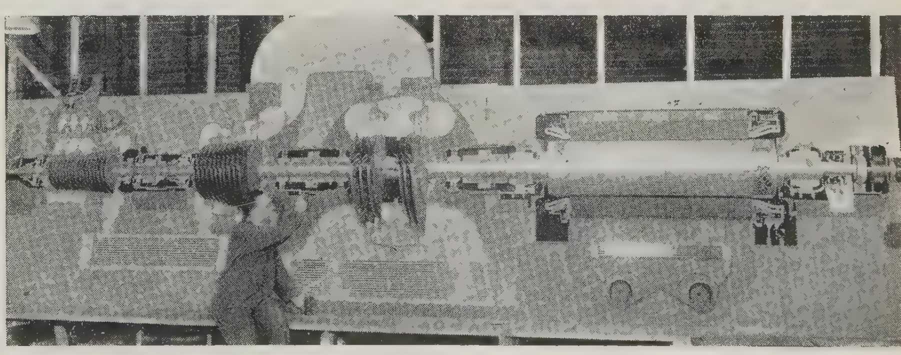
One of the spectacular effects calls for a battery of 24 arc searchlights having a total light output of 1,920,000,000 cp. In contrast to this intense blaze of light at the south end of the fair grounds will be the spots of light and color produced by 500 mushroom-like lighting fixtures set in the ground in gardens and along paths.

A Century of Progress Exposition, Chicago World's Fair—1933



Parts of the immense diorama which will depict the generation, distribution, transmission, and utilization of electricity at the Century of Progress Exposition, Chicago, 1933. On the left is a low-head hydroelectric station with transmission and distribution systems serving rural communities, and on the right is a model city and steam-electric generating station

On the left, E. B. Frost, former director of Yerkes Observatory, Williams Bay, Wis., C. T. Elvey, specialist in stellar photometry, and Otto Struve, present director, examine the photoelectric devices which will be installed there to aid in the opening of the exposition by a 40-year-old beam of light from the star Arcturus



As part of the electrical central station industry exhibit at A Century of Progress Exposition, Chicago, 1933, a conventionalized diagram of the latest type steam turbo-generator will be exhibited. It is one-quarter full size

Doctor Thomson Honored at Gathering of Engineers and Scientists

THE 80th birthday of Prof. Elihu Thomson (A'84, F'13, HM'28, member for life, and past-president), dean of electrical engineers, was celebrated at the Massachusetts Institute of Technology, Cambridge, on Wednesday, March 29, 1933, by a scientific conference, an historical exhibit, and a testimonial dinner. The celebration was arranged by a committee of 45, representing Professor Thomson's earliest associates, the scientific and professional societies, the electrical industries, and education. Prof. D. C. Jackson (A'87, F'12, and past-president), head of the department of electrical engineering of the Massachusetts Institute of Technology, was chairman of the committee.

The scientific conference was held in the afternoon and was presided over by Professor Jackson. The lectures dealt with modern theories and experiments in the field of electricity, and with the historical developments of its applications, the latter with particular reference to Professor Thomson's own contributions. The first, on "Electron Theory of Metallic Conduction," was given by Prof. J. C. Slater, head of the department of physics at the Massachusetts Institute of Technology. "Electricity Released From Matter" was the subject of Dr. Karl K. Darrow (A'19), Research physicist of the Bell Telephone Laboratories, New York, N. Y., and the "Significance of Professor Thomson's Work in the Development of Electrical Engineering was discussed by Dr. Karl T. Compton, president of Massachusetts Institute of Technology. The conference was attended by a group of some 250 guests, members of the instructing staff, and graduate students.

An unusually interesting exhibit showing a number of Professor Thomson's many inventions was arranged in Walker Memorial. The exhibit included a bi-phase dynamo electric machine, invented and built by Professor Thomson in 1878, which had both a commutator and slip rings and therefore could deliver alternating and direct current. This machine was shown at the Franklin Institute in 1879. There were also shown several early type transformers, 2 of which were used with the 1878 dynamo. A working model of one of the first constant-current transformers, now so widely used, was an interesting part of the exhibit. Several different pieces of apparatus showing the discovery and application of the important principle of electromagnetic repulsion were exhibited. Two types of commercial machines shown included a series arc lighting machine with a spherical armature, built in 1879, and equipped with a brush shifting device to maintain a constant current. The armature had 3 coils and the commutator 3 segments. It is believed that this is the first dynamo to have a 3-phase winding. A similar machine was built in 1886 for multiple incandescent lighting. Early types of arc lamps were also shown. Among the instruments shown were 2 watthour meters whose development exerted a large influence in that they were the first to make it possible to measure readily the transfer of power. Some early welding transformers were also of interest. In addition there were several inclined-coil portable measuring instruments.

The celebration was climaxed by a testimonial dinner held in Walker Memorial in the evening, at which Doctor Compton presided. The opening address of tribute to Professor Thomson was given by Joseph B. Ely, Governor of Massachusetts, who spoke on behalf of the citizens of the commonwealth. G. B. Cortelyou, president of the Consolidated Gas Company of New York and of the Edison Electric Institute, paid the tribute of the electrical industries, and H. P. Charlesworth (M'22, F'28, and president), president of the A.I.E.E., spoke for the American engineering societies. Dr. Harvey W. Cushing, eminent surgeon, greeted Doctor Thomson in the name of scientific professions other than engineering. Dr. Vannevar Bush (A'15, F'24), vice-president and dean of engineering at M. I. T., spoke on behalf of educational institutions, and E. W. Rice, Jr. (A'87, F'13, and past-president), honorary chairman of the board of directors of the General Electric Company, took as his topic "My Professor."

Prof. Elihu Thomson shows his first electric dynamo to E. W. Rice, Jr. (right) when engineers, scientists, and educators from all parts of the country gathered to honor him on his 80th birthday. This dynamo, similar to the Edison machine built 6 years later, was later operated as a motor being driven by a foot operated generator built by Prof. Thomson

In his response, Professor Thomson expressed deep appreciation for the many tributes, and recalled some of the interesting experiences of his long career. At the conclusion of the dinner, at which nearly 250 guests were present, President Compton announced plans for the establishment of an Elihu Thomson professorship in electrical engineering to be effective as soon as funds were available.

The address which President Charlesworth delivered on behalf of the American engineering societies follows:

President Charlesworth's Address to Doctor Thomson

"As a representative of our great engineering societies and especially on behalf of the thousands of your fellow members in the American Institute of Electrical Engineers, I bring you, Doctor Thomson, greetings on this happy occasion.

"In research and engineering you have engaged with remarkable success for 60 years. To realize your quick perception of the fundamentals in the science of electricity, we have but to recall that as early as 1875 you were investigating those electromagnetic phenomena which we today classify as radio. In 1877, turning your attention for a time of mechanics you made the basic invention of a means for separating by centrifugal force parts of a fluid which differ in density. This method you called 'a process of skimming cream mechanically,' which also proved to widespread value in far reaching fields. By 1882—over 50 years ago—you had assumed another position of leadership in that new industry of lighting by electric arcs, which has done so much in our towns and cities to insure comfort and safety in the hours of night.

"By these investigations and your hundreds of inventions you have contributed enormously to the advance of all the engineering arts, notably electrical, mechanical, and chemical. However, your contributions always went further than these individual activities, for you published your results and methods in scientific papers and otherwise. Your enthusiasm and your technique you passed on to hundreds of engineers, first as a professor, later as a director of the laboratories which bear your name, and finally as a great leader in your profession. Your fruitfulness you shared with others whom you trained and inspired. Your whole life has indeed been in accord with, and in fact has greatly contributed to, the highest ideals of the engineering profession. It is not surprising, therefore, that we find your name among that illustrious group who were the charter members of our great society, the American Institute of Electrical Engineers, which ever is endeavoring to perpetuate these high ideals.

"You have contributed immeasurably in the important work of our society; and in many other technical organizations you have taken an active part and served with distinction. You have represented us in international electrical congresses and on tech-

nical commissions, bringing about unity of agreement and common plans of action of far reaching importance not only to the profession but to the good of mankind generally. It is small wonder, therefore, that we find your fellow engineers have given expression of their gratitude by conferring upon you the high honor of president of our great society and by later making you an honorary member, also that they should have conferred upon you that unusual distinction of making you the first recipient of the Edison Medal, the highest honor within our power to confer on any of our associates.

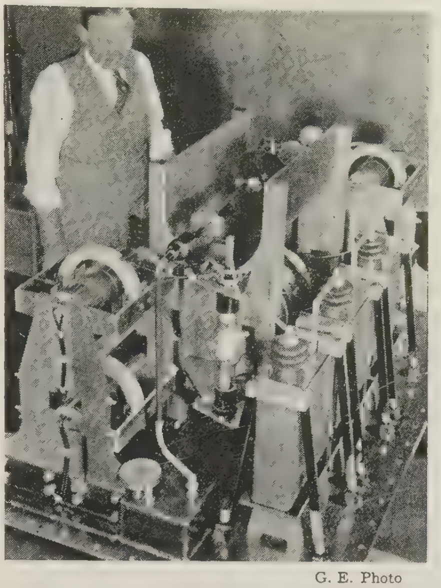
"Not only have these public recognitions of your meritorious achievements in engineering and industrial progress come to you from our own society but they have been world wide in scope. In 1889 you received the Grand Prix in Paris and were decorated by the French Government, as Chevalier and Officer of the Legion of Honor for electrical research and invention. In 1904 in our own country at the St. Louis Exposition you received the grand prize for electrical work. In 1916 you received the John Fritz Medal from the 4 founder societies. You have been made an honorary member of The American Society of Mechanical Engineers, have been president of the International Electrotechnical Commission, and time and time again in more recent years your illustrious accomplishments have been recognized by the highest awards in the power of scientific and other organizations both here and abroad.

"By your accomplishments and by the universal recognition which they have received, you have brought honor not only to yourself, but to the whole profession of engineering. We glory in these honors, and in behalf of your fellow engineers everywhere, I bring you, sir, these words of congratulation and appreciation, and extend to you and those dear to you our best wishes for the years to come."

Current Hydraulic Laboratory Research.—A report has been compiled by the U.S. Bureau of Standards on "Current Hydraulic Laboratory Research in the United States." The compilation and distribution of the information contained in this report respresents a cooperative attempt on the part of the hydraulic laboratories in the United States to bring about the effective interchange of information relating to research projects which are being carried on in these laboratories. In the past, hydraulic investigations have been conducted independently in the various hydraulic laboratories, for the most part without any one laboratory having any detailed knowledge of what the others were doing. In this report, some 100 laboratory projects are listed, and information is given on the title of the project, the purpose, names of investigators, correspondent, method and scope, progress, and general remarks. At the present time the general listing of investigations which have been completed in the past is not contemplated, although this may be undertaken later. It is stated that a second progress report will be issued on July 1, 1933, and a form is included in the first report which may be of assistance to laboratories wishing to cooperate in this work.

X-Ray Unit for Hoover Dam Penstocks

Every inch of steel welds for a distance greater than 75 miles in the penstocks for Hoover Dam will be minutely inspected by X-rays. A special shock-proof apparatus rated at 300,000 volts has been designed for this job, the high voltage system before immersion in oil being pictured here.



G. E. Photo

Complete safety in dealing with such high voltages, space limitations, and the necessity for easy portability were problems encountered in the development of the apparatus. The penstock contract for the dam was awarded with the provision that all fusion welds pass X-ray inspection. The penstock sections range from $8^1/_2$ to 30 ft in diameter, and the thickness of the steel is 3 in. in many places. These giant sections will be welded circumferentially and longitudinally, a job calling for a minimum of 159,000 separate X-ray exposures, involving the use of more than 24,000,000 sq in. of X-ray films. To cope with this unusual problem and keep up with the planned construction schedule, X-ray apparatus of a new type was necessary. Rated at 300,000 volts and 10 milliamperes for continuous operation, it is capable of producing radiographs of welded steel plate of 4-in. thickness.

Electrical safety is obtained by immersing the transformer, condensers, tubes, and the X-ray tube itself in oil, within a sealed and grounded tank. The tank has adequate internal lead shielding to insure perfect X-ray protection as well. A single cable bringing the low voltage power supply is the only electrical connection.

The apparatus consists of 3 units—a shock-proof head weighing 5,000 lb, the operator's control unit, and an expansion tank. The anode of the X-ray tube will be cooled by oil, circulated by a motor driven pump. The head will be mounted on a special mechanical carriage so designed that it can work inside or outside of the penstock, traveling on a narrow gage track.

District Meeting at Schenectady, May 10-12

The Institute's North Eastern District meeting will be held in Schenectady, N. Y., May 10–12, 1933, with headquarters at the Hotel Van Curler, which is located a short distance from the main entrance to the General Electric Company's Schenectady works. The program of the Schenectady District meeting was announced in ELECTRICAL ENGINEERING for April 1933, p. 271–3; abstracts of all papers available at the time of going to press are included in the present issue.

A report of the Schenectady meeting is scheduled for the June issue of ELECTRICAL ENGINEERING, and a summary of the discussion on the papers will be presented as soon as they are made available by the discussors. To be considered for publication discussions should be written and mailed to the A.I.E.E. editorial department, 33 West 39th Street, New York, N. Y., on or before May 26, 1933.

Mazda Lamp Efficiencies Increased

Changes have been made in the design of 75-watt and 100-watt mazda lamps whereby, although the design life has been reduced, the price also has been reduced and the efficiency has been increased. The net result should be a saving to the user.

The design life of both the 75-watt and the 100-watt mazda lamps has been reduced from the former value of 1,000 hrs to the new value of 750 hrs. The price of the 75-watt lamp has been reduced to 20 cents and the 100-watt lamp to 25 cents, both previously having been listed at 35 cents; this reduction in cost amounts to 43 per cent and 29 per cent, respectively, in both cases a greater percentage of reduction than the reduction in life. As both lamps have a 4 per cent increase in efficiency, the net cost of light will be decreased.

The 100-wattmazda lamp still has an A-23 bulb, but the 75-watt lamp has been changed from an A-23 to an A-21 bulb.

Construction Industry Statistics Published.—Announcement is made by American Engineering Council that the bureau of the census, U.S. Department of Commerce, has published a summary of statistics relating to the construction industry as gathered during the 15th census of the United States, 1930. These statistics, compiled from reports received from 144,396 individuals, partnerships, or firms engaged in the construction industry, show the organization and geographical distribution of the industry. A survey of construction during 1929 analyzes construction costs, materials, labor, and equipment, and classifies the types of construction work performed. The statistics are presented by states, by regional areas and for the United States as a whole. This publication can be secured from the superintendent of public documents, Washington, D. C., at 20 cents per copy.

Letters to the Editor

CONTRIBUTIONS to these columns are invited from Institute members and subscribers. They should be concise and may deal with technical papers, articles published in previous issues, or other subjects of some general interest and professional importance. ELECTRICAL ENGINEERING will endeavor to publish as many letters as possible, but of necessity reserves the right to publish them in whole or in part, or to reject them entirely.

STATEMENTS in these letters are expressly understood to be made by the writers; publication here in no wise constitutes endorsement or recognition by the American Institute of Electrical Engineers.

Reactive Volt-Ampere Conventions

To the Editor:

The various conceptions of reactive power presented in recent committee reports and in articles in ELECTRICAL ENGINEERING (see April 1933 issue, p. 259–70) illustrate how differently we can view the most familiar elements of electrical theory, while Dr. Silsbee's analysis (p. 261–2, April issue) of possible reasons for selecting the sign of reactive power indicates how difficult it is to agree on even the simplest conventions. Dr. Silsbee leans to the choice of a positive sign for inductive volt-amperes on the basis of general principles of scientific convention. J. A. Johnson reaches the same conclusion on the basis that inductive power is commonly generated and distributed just as real power is, so that it is convenient to use the same sign for both. On the other hand, numerous writers consider inductive power as negative for the same reasons that inductive currents are called lagging and are plotted downward, while A. E. Knowlton's reported questionnaire shows 50 representative engineers to be about equally divided in opinion.

Clearly, no agreement is possible unless a conclusion can be reached from universally accepted definitions without bringing in any assumptions whatever.

What is the physical meaning of the angle between the active and reactive power vectors? Active power flows continuously in the same direction in each conductor of the system, while reactive power flow alternates in direction in each conductor at double line frequency. The combination of active and reactive power is, therefore, exactly analogous to that of the direct and alternating components of a pulsating unidirectional current. In each case the 2 quantities have different frequencies, and so cannot properly be represented by vectors in a common time diagram. No physical reality can be ascribed to the angles in a right-angled triangle representing the a-c and d-c components of a pulsating current. However, the right-angled triangle representing the active and reactive volt-amperes in an a-c system is geometrically identical with the representation of the in-phase and out-of-phase components of voltage or current in the same system.

By universally established conventions, an inductive impedance is represented by the expression:

$$Z = R + jX \tag{1}$$

which results in the expressions:

$$V = (R + jX)I \tag{2}$$

for the vector voltage referred to the current as reference axis and

$$I = \left(\frac{R - jX}{R^2 + X^2}\right)V \tag{3}$$

for the vector current referred to the voltage as reference axis.

In dealing with constant current systems, it is the general practice to use eq 2, and hence to represent inductive voltages as positive. The vector diagrams so obtained represent active and reactive power equally as well as in-phase and reactive voltages.

In dealing with constant voltage systems, it is the practice to use eq 3, and hence to represent inductive currents as negative. These vector diagrams equally well represent active and reactive power as they do in-phase and inductive currents.

Whatever system is being considered, vector diagrams of voltages and currents are useful and are generally employed. It is obviously convenient to use the same diagrams to represent the power relations. In fact, it seems ridiculous to do otherwise, as the diagrams are geometrically identical, and as no physical reality can be attached to the angles in the power triangle considered by itself. The angles in the current and voltage triangles represent time phase in degrees, or in fractions of a cycle.

It is thus apparent that inductive volt-amperes should be defined as positive, to match the inductive voltage (eq 2) if the current is considered as the reference axis. This is the normal convention for constant current systems. Also, inductive volt-amperes should be defined as negative, to match the inductive current (eq 3), if the voltage is considered as the reference axis. This is the normal convention for constant voltage systems.

Both conventions are equally acceptable and equally in accord with the already well established standards. Hence, both must be permitted, and the only possible grounds for selecting one as standard are convenience and usage.

The very great predominance of constant voltage systems in power transmission and other cases where reactive power diagrams are of practical interest makes it convenient to adopt as standard the convention of plotting inductive power as negative. A review of the literature indicates a gradual trend of usage toward the negative sign for inductive volt-amperes, although the total number of references is about equally divided.

If it is realized that vector power diagrams have no physical reality, but are simply representative of currents or voltages no difficulties can arise, but it is obvious that whether currents or voltages are implied must always be stated. If, as Dr. Silsbee has done, we attempt to define the sign of reactive power from a logical analysis of the underlying definitions, we are immediately involved in such questions as whether the susceptance, B, is $\frac{X}{Z^2}$ or $-\frac{X}{Z^2}$, and the discussion loses all physical significance.

An over-excited synchronous generator delivers inductive volt-amperes, and is properly called a lagging power factor generator. An under-excited synchronous motor receives inductive volt amperes from the system, and is so properly called a lagging power factor motor. With the standard counterclockwise rotation of vectors, the term lagging definitely connotes a downward plotted, or negative vector.

The evidence presented here from the points of view of both convenience and usage, therefore, indicates that inductive volt-amperes should be considered negative. If, however, it is desired to use the current as a reference axis and take inductive volt-amperes positive, this is just as correct and legitimate as it is to treat the power of a motor as positive. The real difficulty with reactive volt-amperes is that they have 2 signs, one for angle of lead or lag and one for inflow or outflow. The resultant signs for the usual types of power flow recommended as standard are thus as indicated in Table I.

Table I—Recommended Standard Signs

Apparatus	Power	Reactive Volt-Amperes
Over-excited synchronous motor	−	−
Under-excited synchronous motor	−	+
Over-excited synchronous generator	+	−
Under-excited synchronous generator	+	+

Very truly yours,

P. L. ALGER (A'17, F'30)
(General Electric Co., Schenectady, N. Y.)

To the Editor:

Volt-amperes is necessarily a vector quantity having a real component and a quadrature component, or if you wish, an active component and a reactive component. Thus in the expression $VA = P \pm jQ$, P is the active component and Q is the reactive component. The term power is generally understood to mean watts, or the active component of the volt-amperes, and with this understanding the term "reactive power" is meaningless.

It is certainly advisable to give a name to the reactive component of volt-amperes. The standardization of such a name is of more importance than the name itself, although the unit "var" seems most appropriate, indicating as it does, reactive volt-amperes.

Mathematically, the sign of the quadrature component depends upon whether we consider $\theta = \alpha - \beta$, or $\theta = \beta - \alpha$, in Fig. 1. In the first case θ is measured from I to E, and in the second case θ is measured from E to I, with a consequent reversal in the sign of $\sin\theta$. This is identical with the effect of the order of vectors when taking vector cross-products, so that $E \times I = -I \times E$.

The angle of lag or lead is understood to be the angle which the current vector makes with the voltage vector, i. e., the current vector is referred to the voltage vector. Thus the angle θ should be measured from the voltage vector to the current vector, and it becomes a negative angle with a

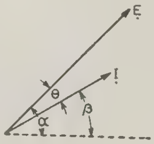


Fig. 1

lagging current, and a positive angle with a leading current. Vars are therefore negative with a lagging current, and positive with a leading current.

The question of clockwise or counterclockwise rotation does not enter directly into the choice of signs, since the double frequency volt-ampere vector has no more place on our Argand diagram than have the stationary impedance or admittance vectors. However, if we consider vector volt-amperes on a separate diagram, there appears to be a consistency in associating $-jQ$ with a lagging power factor and $+jQ$ with a leading power factor. This is in agreement with the convention just outlined.

Letting $\underset{\cdot}{E} = (e_1 + je_2)$, and $\underset{\cdot}{I} = (i_1 + ji_2)$, we may write

$$\underset{\cdot}{VA} = (e_1i_1 + e_2i_2) + j(e_1i_2 - e_2i_1),$$

and using vector notation

$$\underset{\cdot}{VA} = E \cdot I \pm j \,|\, E \times I \,|,$$

the sign of the quadrature component being determined as above.

Very truly yours,
Wm. B. Nulsen (M'27)
(Ass't Prof. of Elec. Engg., University of New Hampshire, Durham, N. H.)

Private Versus Public Enterprise

To the Editor:

I wish to offer some comment on the 2 points of view regarding "Public Versus Private Enterprise" expressed by Professor Rautenstrauch and Doctor Jordan in the April 1933 issue of Electrical Engineering, p. 234–7.

Perhaps the fact that the material presented is merely excerpts from the original papers may explain the impression, obtained from reading, that both parties have made some general observations and then abruptly "jumped at conclusions." Referring first to the remarks of the first gentleman named above—it is clear to all thinking people that what is for the immediate financial good of the owners of one particular business may not be for the good of society as a whole. And certainly it is apparent that the willy nilly laissez faire operation of rugged individualism unrestrained has not led our civilization into a state of stability with the maximum of security for the individuals. But we may question the finality and absoluteness of the author's statement. "Each unit of the industrial system, private, corporate, and even public, operating on the basis of immediate profit, is not responsive to human need." Professor Rautenstrauch has not established proof that complete socializing of industry is the logical solution. In fact, he does not state such a conclusion, although the form in which the arguments are presented leads one at first to believe that they are in the nature of a debate with the first speaker upholding the affirmative on the advantages of putting industry in general on a public enterprise basis.

Professor Rautenstrauch's enumerated conclusions are mild enough, so that it is apparent no complete revolution is contemplated. I offer the suggestion that a great deal might be said on conclusion number 4, in regard to what is meant by dividends on common stock being earned. If a greater income is secured by a reduction of wages and maintenance of selling price, is it truly "earned," from a social point of view?

Now turning to Doctor Jordan's remarks glorifying private initiative, the author seems to be blissfully ignorant that the competitive system, operating largely on a laissez faire basis, has failed utterly to bring stability and security. I know that Doctor Jordan is not unaware of what has happened; but no discussion of this nature can be complete which neglects the social aspect. We have been mad in achieving material progress and technological advance while neglecting to build the entire system in such a way that it may function reliably as a whole. I hasten to say that we do not need less of materialistic engineering, but rather more of economic engineering with socialized objectives.

I suggest that the specific remarks to the effect that no constructive economic planning in a large sense has been achieved, and that we are realizing the futility of government, may be a little premature or a bit pessimistic. Certain things have not been done—but who can deny the distressing need nor conclude that we must fail because we have only seen failure so far?

Now I believe, as is generally the case when 2 extremist views are presented, that the sensible and certainly the practical conclusions are in a compromise along lines which hold some hope of being workable as correctives for the essential difficulties in which we find ourselves enmeshed.

If business will not or cannot exercise proper self control to assure reasonable security for the individual, then the people as a whole must bring about the necessary degree of control (but to no greater extent than is necessary since if we aim at a Utopia we would at best end in the deplorable condition which may be suggested by the words, United States of Soviet America). If our present government is not a satisfactory instrument to administer this control, it must be modified to that end—or a separate suitable agency will have to be evolved.

The idea of killing individual initiative is an alarmist view. First, we are not going that far in socializing industry. Secondly, students of human nature know that individual initiative is an individual thing—some have more and some have less. Although there may be a real decrease in the expression of such initiative caused by the removal of the stimulus of keen necessity; yet the principal stimulus is merely an environment where things are moving and work is being done. Doctor Jordan would not sit all day with his feet on his desk just because his pay check was signed by Secretary Woodin.

Very truly yours,
C. T. Button (A'26)
(1133 Chamber of Commerce Bldg., Cincinnati, Ohio)

Excessive Bank Deposits and the Business Depression

To the Editor:

There is one contributing cause of the present depression that has not received the attention that it deserves, and that is the excessive amount of bank deposits that has been accumulating in recent years. The curves of Fig. 1 shows the increase of these deposits since 1914, an increase to nearly 3 times, while the actual money in the bank vaults decreased. The curves include commercial banks, trust companies, and saving banks. They do not include money in the U.S. Treasury or the Federal Reserve banks. It is true that the Federal Reserve banks are prepared to aid the regular banks in time of need, but most of the apparently

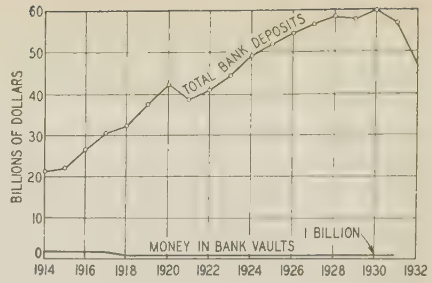


Fig. 1

large supply of gold in reserve is held as a reserve for currency in the hands of the public. Only a small amount remains for aiding the banks, as compared with the vast amount of deposits.

In 1928 many people, including a prominent engineer, were pointing to the great increase in bank deposits as a source of strength. They should have pointed to them as a warning. Bank deposits are debts, looked at from the other end. The only difference between them and other debts is that the bank acts as an intermediary. Particularly savings bank deposits are a source of danger, because so large a part of them consist of real estate mortgages and other investments that cannot be easily turned into cash.

To describe the situation briefly, there is a vast army of creditors who have the right to demand a total of about $60,000,000,000 from the banks, but the banks do not have either the actual money or the power to collect more than a very small fraction of it from the debtors without upsetting the whole financial and business structure.

Is it not perfectly plain that a great increase in debts, such as this curve shows is an element of danger? Private debts are bad enough, but bank deposits are a particularly dangerous form of debts, because the creditor feels that he has the right to demand the payment at a moment's notice. A few of us called attention to this danger back in 1928. Now that we are witnessing the results, the danger should be clear to all.

Very truly yours,
A. W. Forbes (A'12)
(Forbes and Myers, Worcester, Mass.)

Duplex Balance of Submarine Telegraph Cable

To the Editor:

An article, "Impedance Curves of a Composite Cable," by M. I. Pupin appearing in the February 1933 issue of Electrical Engineering, p. 115–8, discusses the problem of the duplex balance of a submarine telegraph cable composed of loaded and unloaded sections.

In the next to the last paragraph of his article, Dr. Pupin states: "Composite cables employ high speeds of transmission, hence they demand a balancing at higher frequencies; no balancing methods known today can give sufficiently satisfactory results when applied to such cables." It is perhaps worth while to refer to a paper "The Newfoundland-Azores High-Speed Duplex Cable" by the writer and G. A. Randall which was presented at the A.I.E.E. winter convention in 1931, and published in abstract in the May 1931 issue of Electrical Engineering, p. 337–9. This paper described the original composite cable de-

signed and laid by the Western Union Telegraph Company in 1928, and stated that a duplex speed of 42 cycles had been obtained. Subsequent to the preparation of the paper, as indicated in the discussion appearing in the A.I.E.E. TRANS., June 1931, p. 396, an improved balance was obtained, satisfactory for operation at 50 cycles. The cable has been in continuous duplex operation since May 1930. Although transatlantic cable traffic has not been such as to require commercial operation at the maximum duplex speed, it is interesting to note that in a recent test, after an interval of about 2 years, the circuit operated satisfactorily at 50 cycles duplex, and this without preliminary readjustments!

Theory previously published shows that for satisfactory duplexing, the impedance of the balancing network or artificial line must match that of the cable to a high degree of accuracy throughout a frequency range from about $^1/_2$ the fundamental signaling frequency to about 1.6 times that frequency, and all frequencies from zero to twice the signaling frequency must be considered.

In the article by Dr. Pupin, he proposes to balance a composite cable by means of an artificial line of type which is *uniform* throughout its length. The artificial line is to consist of a series of similar inductive networks. The curves given by him show that the resulting artificial line matches the impedance of the cable only at the higher frequencies of the range under consideration. In his conclusion Dr. Pupin states that the inductive networks alone will not satisfactorily balance a cable for high speed operation, and that a supplementary network of undetermined design must be used to overcome its shortcomings.

Such a supplementary network may perhaps be developed, but until it has actually been accomplished there must remain a question as to the practicability and efficiency of the whole plan.

It is also noted that for purposes of illustration Dr. Pupin has assumed the loaded portion of the cable to have inductance of but 30 mh per nautical mile, as compared with loading tapered from 56 mh to 230 mh per mile in the Newfoundland-Azores cable previously referred to. The use of lower inductance would make easier the design of the balancing artificial line, but in general would result in increased cable attenuation which in turn would limit to a lower value the possible speed of the cable.

The artificial line network for the Newfoundland-Azores composite cable was calculated to match the actual cable, section for section, and thus contains a portion similar to non-loaded cable and another portion similar to loaded cable. It provides an impedance match of sufficient accuracy over the relatively wide frequency range from zero to 100 cycles. Experience has shown that this balancing method is suitable for even higher speeds than those given; the maximum speeds are not limited by any deficiencies of the balancing network; rather they are limited by the electrical attenuation of the cable, which in turn depends upon the first cost.

Dr. Pupin also presents an original method for calculating the terminal impedance of a composite cable. However, there is available a well known standard formula, which we have found to be quite practical and satisfactory for the purpose, *viz.:*

$$Z_s = Z_0 \frac{Z_0 \sinh kl + Z_r \cosh kl}{Z_0 \cosh kl + Z_r \sinh kl}$$

An alternative expression, sometimes used, is the following:

$$Z_s = Z_0 \frac{1+x}{1-x}, \text{ in which } x = \frac{Z_r - Z_0}{Z_r + Z_0} \cdot \epsilon^{-2kl}$$

In these,

Z_s = the sending-end or "terminal" impedance of the composite cable

kl = the propagation constant of the non-loaded portion

Z_0 = the characteristic impedance of the non-loaded portion

Z_r = the impedance of the loaded portion as would be measured from its end

Very truly yours,
J. W. MILNOR (A'13, F'30)
(Western Union Telegraph Company, New York, N. Y.)

Personal Items

H. P. CHARLESWORTH

H. P. CHARLESWORTH (M'22, F'28, and president) vice-president of the Bell Telephone Laboratories, Inc., New York, N. Y., recently resigned to accept the position of assistant chief engineer of the American Telephone and Telegraph Company, New York, N. Y. Following graduation from Massachusetts Institute of Technology, Cambridge, in 1905, with the degree of bachelor of science, he entered the engineering department of the American Telephone and Telegraph Company at Boston, Mass. Shortly after the close of the war, during which he had been specially assigned to handle problems wherein the Bell System could be of assistance to the government, he became equipment and transmission engineer for the American Telephone and Telegraph Company. In 1920 President Charlesworth was appointed plant engineer of that company, and in 1928 was elected a vice-president of the Bell Telephone Laboratories, Inc. (A more detailed account of President Charlesworth's career was presented in ELECTRICAL ENGINEERING for January 1932, p. 53.)

E. H. COLPITTS (A'11, F'12) assistant vice-president of the American Telephone and Telegraph Company, New York, N. Y., has been appointed vice-president of the Bell Telephone Laboratories, Inc., New York, N. Y., to succeed H. P. CHARLESWORTH (M'22, F'28, and president) who becomes assistant chief engineer of the American Telephone and Telegraph Company. Doctor Colpitts will continue to retain his previous office as well, reporting in both cases to Dr. F. B. JEWETT (A'03, F'12, and past-president) who is vice-president of the American Telephone and Telegraph Company, and president of the Laboratories. In his capacity as assistant vice-president of the telephone company, Doctor Colpitts is in charge of its development and research department. He received the degree of bachelor of arts from Mt. Allison University, Sackville, New Brunswick, Can., in 1893, the same degree from Harvard University, Cambridge, Mass., in 1896, and the masters degree from the latter institution in 1897; in 1926 Mt. Allison University conferred the honorary degree of doctor of laws upon him. After being an assistant in physics at Harvard University for 2 years, he joined the telephone engineering department of the American Telephone and Telegraph Company at Boston, Mass., in 1899, becoming research engineer of the Western Electric Company, New York, N. Y., in 1907. In 1917, he became assistant chief engineer of this latter company, and in 1924, assistant vice-president of the American Telephone and Telegraph Company. During the war he was engaged in a study of modern methods of military communication. He has been granted many patents on telephonic apparatus, and has been the author of many technical papers. He is a fellow of the Institute of Radio Engineers, the American Physical Society, and the Acoustical Society of America, and a member of the American Chemical Society, the Harvard Engineering Society of New York, and the Telephone Pioneers of America.

E. H. COLPITTS

WILLIAM MCCLELLAN (A'04, F'12, and past-president) formerly vice-president of the Stone & Webster Engineering Corp., New York, N. Y., has been elected president of the Potomac Electric Power Company, Washington, D. C. Mr. McClellan also was made a director of the company. Following graduation from the University of

Pennsylvania in 1900 with the degree of doctor of science, he continued in postgraduate work, receiving the degree of doctor of philosphy in 1903. During the period of 1900 to 1905, he was instructor in physics at this university and was also employed by the Philadelphia Rapid Transit Company, rising to the position of engineer in charge of construction. He was with Westinghouse, Church, Kerr & Company, New York, N. Y., from 1905 to 1907, and a member of the firms, Campion-McClellan Company 1907–1915; Paine, McClellan & Campion, 1915–1920; and McClellan & Junkersfeld, 1922–1929. In 1929 he was elected vice-president of the Stone and Webster Engineering Corporation. He served as dean of the Wharton School of Finance and Commerce, University of Pennsylvania, from 1916–1919, and was vice-president of the Cleveland Electric Illuminating Company, 1919–1921. For about 3 years, 1911–1913, Doctor McClellan was consulting engineer and chief of division of light, heat, and power of the public service commission, 2nd district, New York State. After resigning from this work, he organized and managed the rate investigation of the New York Telephone Company for the commission. During the war, he was director of the intercollegiate intelligence bureau in Washington, an association of the principal colleges and universities of the United States to assist the government in obtaining trained men. In 1925 he was selected by President Coolidge as a member of the Muscle Shoals commission. He is a member of The American Society of Mechanical Engineers, the American Transit Association, Phi Beta Kappa, Sigma Xi, and is a trustee of the University of Pennsylvania. Doctor McClellan has been active in the Institute, having served on many committees.

R. E. HELLMUND

R. C. MUIR

W. H. HARRISON

R. E. Hellmund (A'05, F'13) formerly chief electrical engineer for the Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa., has been appointed chief engineer of the company. Mr. Hellmund is the first to hold this office since the death of B. G. Lamme in 1924. Mr. Hellmund was born in Gotha, Germany. He graduated from the Technical Institute of Ilmenau, Germany, worked 3 years, then continued his studies at Charlottenburg University, Berlin, graduating in 1899 with the degree of electrical engineer. After being engaged in the development of d-c and a-c machines and high voltage cables for concerns in Germany, he came to the United States in 1903, being first engaged in the design of a telegraphic device for transmitting drawings. During the first half of 1905, he was associated with William Stanley of Great Barrington, Mass., on the development of a self-compounded alternator and low-frequency exciter. Between 1905 and 1907, he was in the engineering department of the Western Electric Company, at Hawthorne, Ill., where he was in charge of all a-c motor design for the company. Since October 1908, he has been with the Westinghouse Electric and Manufacturing Company, where, after 2 months he was placed in responsible charge of extensive development work on various kinds of induction motors. He was later in charge of all design of d-c and a-c railway motors. In 1917, he was assigned miscellaneous consulting duties, in which he continued until 1921 when he was appointed engineering supervisor of development. In 1926, he was made chief electrical engineer. Mr. Hellmund has presented many papers before the Institute, has served on its standards committee 1930–33, and was awarded its Lamme Gold Medal in 1929.

R. C. Muir (A'08, M'19) who for 3 years was assistant to the late C. E. Eveleth (A'06), vice-president in charge of engineering for the General Electric Company, Schenectady, N. Y., has been appointed manager of the engineering department of the General Electric Company. In his new capacity, Mr. Muir will have direct charge of the company's designing engineering in all of its various plants, the works laboratories, and the general engineering laboratory at Schenectady. Mr. Muir graduated from the University of Wisconsin, Madison, in 1905 with the degree of B.S. in E.E. Immediately after graduation he entered the student engineering course of the General Electric Company, at Schenectady, N. Y., and has been with the company continuously since that time. In 1907 he was transferred to the central station engineering department of the company, and in 1908 joined what is now the industrial engineering department. Following extensive work in the application field, Mr. Muir was appointed chief commercial engineer of the International General Electric Company when it was organized in 1919. Following 3 years in this position he was again promoted, this time becoming assistant engineer of the industrial engineering department at Schenectady, where he was responsible for application engineering for all types of industries. In 1930 Mr. Muir became general assistant to Mr. Eveleth in general charge of the designing engineering department and works laboratory.

W. H. Harrison (A'20, M'30, F'31) plant engineer of the American Telephone and Telegraph Company, New York, N. Y., has recently been appointed operating vice-president of the Bell Telephone Company of Pennsylvania with headquarters in Philadelphia. Following graduation from the electrical engineering course of Pratt Institute, Brooklyn, N. Y., Mr. Harrison joined the New York Telephone Company, New York City, in 1909 as repairman. Between 1911 and 1915, he was in the repair shop of this company engaged on apparatus inspection, assembly, and wiring work. Between 1915 and 1918 he was in the engineering department of the Western Electric Company following which until 1924 he was in the engineering department of the American Telephone and Telegraph Company. From this date until 1929 he was equipment and building engineer of the company, becoming plant engineer in 1929. Among his Institute activities he is chairman of the technical program committee, and a member of the committees on publication and coordination of Institute activities. (For a more detailed account of Mr. Harrison's career see Electrical Engineering for July 1932, p. 529.)

H. W. Cope (M'16) formerly assistant director of engineering, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa., has recently been appointed assistant to the vice-president, responsible for the coordination of certain headquarters engineering departments and district office engineers. Mr. Cope, a native of North Vernon, Ind., studied at Franklin College, Franklin, Ind., and Purdue University, Lafayette, Ind., receiving the degree of B.S. in E.E. from the latter institution in 1898. Since that year he has been in the organization of the Westinghouse Electric and Manufacturing Company. He spent successively one year in the testing department, 3 years as switchboard engineer, 4 years as commercial engineer, then 4 years as manager of the a-c department, with executive and engineering duties. The following 4 years he was assistant manager of the industrial and power department of the company. In 1914, he became director of exhibits of the company at the Panama Pacific International Exposition in San Francisco, Calif., returning to East Pittsburgh in 1916 as assistant to the manager of engineering. In 1920 he was appointed assistant director of engineering.

M. L. Sindeband (M'21, F'26) has been elected vice-president and a member of the board of the Ohio Electric Power Company and the Reserve Power and Light Company, with offices in Marion. He also has been named permanent receiver of the

Columbus, Delaware and Marion Electric Company. All of these companies are members of the Ohio branch of the Middle West Utilities system. After being connected with the New York Central Railroad and the Brooklyn Edison Company, he entered the engineering department of the American Gas and Electric Company in 1915, and 3 years later was named electrical engineer of that company. In this position he carried on extensive development work in transmission line and substation standardization and research work on oil circuit breakers and lightning protection. He was subsequently appointed a vice-president of this company, resigning from this office in 1927 to join the American Brown Boveri Company, New York, N. Y., of which he was a vice-president. Mr. Sindeband has to his credit many patents covering automatic train control, saturated core reactors and regulators, carrier-current communication and short-circuit current-control systems. He has presented several papers before the Institute, and has been active on its committees.

C. L. Clarke (A'84, F'12, and Member for Life) retired General Electric employee and one of the Edison Pioneers, was presented with a medal commemorating his charter membership in The American Society of Mechanical Engineers at a joint meeting of the Schenectady Sections of this society and of the A.I.E.E., held in March 1933. At the time of becoming a member of the A.S.M.E. in 1822, Mr. Clarke was chief engineer of the old Edison Electric Light Company, having been appointed by Thomas A. Edison. At that time Mr. Clarke was assisting the inventor in the equipment and layout of the historic Pearl Street electric generating station. At the time of his retirement about 2 years ago, Mr. Clarke was a consulting engineer in the research laboratory of the General Electric Company.

S. R. Inch (A'04, M'13) formerly vice-president, Electric Bond and Share Company, New York, N. Y., was recently elected president to succeed V. E. Groesbeck who became chairman of the board upon the retirement of S. Z. Mitchell. Mr. Inch was born in England in 1878, coming to this country in 1900. He joined the Electric Bond and Share group in 1912, as general superintendent of the Utah Power and Light Company, Salt Lake City. Five years later he was elected vice-president and general manager of this company, holding this office until 1924 when he was transferred to New York, N. Y., as a vice-president of the Electric Bond and Share Company. In 1931 he was made executive vice-president.

F. W. Peek, Jr. (A'07, F'25) chief engineer of the Pittsfield works of the General Electric Company, Pittsfield, Mass., has been appointed representative of the U.S. national committee of the International Electrotechnical Commission on an international subcommittee of the advisory committees on rating of electric machinery and standard voltages and codes. This subcommittee is to make a detailed study of the proposals which have been made by the various countries on the question of sphere gap calibrations.

L. V. Sutton (A'11) formerly vice-president and general manager of the Mississippi Power and Light Company, Jackson, Miss., and for the last several months with the Carolina Power and Light Company, Raleigh, N. C., has recently been elected president and general manager of this latter company. In assuming his new duties, Mr. Sutton is returning to the organization with which he first entered the electric light and power industry in 1912.

A. P. Denton (A'06, F'27) who formerly was engineering director of the armored cable section of the National Electrical Manufacturers Association, New York, N. Y., has been retained as consulting engineer to the rigid conduit industry and its technical committee, to have charge of all technical work relating to codes and standards as well as to guide a program of research and standardization now being undertaken.

R. W. E. Moore (M'17) who at one time was engineering manager of association activities for the Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa., and more recently director of publications for the National Electric Manufacturers Association, New York, N. Y., is now electrical engineer for the National Electric Products Corporation, Pittsburgh, Pa.

E. A. Crellin (A'13, F'28) assistant engineer, division of hydroelectric and transmission engineering, Pacific Gas and Electric Company, San Francisco, Calif., continues for the coming year as director of the San Francisco Electrical Development League. He is a past chairman of the Institute's San Francisco Section, having served for the year 1931–32.

A. G. Jones (A'07) manager, central station department, General Electric Company, San Francisco, Calif., continues as director for the coming year for the San Francisco Electrical Development League. For the 18 years between 1911 and 1929, Mr. Jones was secretary of the Institute's San Francisco Section.

W. V. Read (A'07, M'26) formerly engineer on electrolysis prevention with the American Telephone and Telegraph Company, New York, N. Y., has announced his entry in this field as a consultant on electrolysis and other corrosion problems. He will maintain his headquarters in New York, N. Y.

Mark Eldredge (A'14, M'20) chief engineer, Memphis Power and Light Company, Memphis, Tenn., has been appointed chairman of the transmission and distribution engineering committee of the Edison Electric Institute, the organization which takes over many of the duties of the National Electric Light Association.

J. Allen Johnson (A'07, F'27 and vice-president) chief electrical engineer, Buffalo, Niagara and Eastern Power Corp., Buffalo, N. Y., has been appointed chairman of the electrical equipment engineering committee of the newly formed Edison Electric Institute.

H. W. Crozier (A'03, M'12) consulting engineer, San Francisco, Calif., continues as director of the San Francisco Electrical Development League for the coming year. He was chairman of the Institute's San Francisco Section for 1912–13.

R. A. Hopkins (M'19) formerly electrical engineer with the Stone and Webster Engineering Corp. at Boston, Mass., has established a consulting electrical engineering practice with headquarters at Weston, Mass.

E. E. Kime (A'30) formerly manager of the Needles Gas and Electric Company was recently appointed division manager of West Coast Power and Western States Utilities Company's properties in Utah, Nevada, Wyoming, and Idaho.

C. R. Jones (A'16, M'30) assistant Northeastern transportation manager, Westinghouse Electric and Manufacturing Company, New York, N. Y., has been elected chairman of the Institute's Section for the year 1933–34.

A. F. Dixon (A'14, F'26) director of systems development, Bell Telephone Laboratories, Inc., New York, N. Y., has been elected a member of the executive committee of the Institute's New York Section for the year 1933–34.

D. M. Simmons (A'22, F'28) chief consulting engineer, General Cable Corp., New York, N. Y., has been elected a member of the exeutive committee of the Institute's New York Section for the year 1933–34.

C. G. Marconi (A'24, M'32) formerly with the design division of the Electric Bond and Share Company, New York, N. Y., is now electrical engineer for P. R. Moses and Associates, consulting engineers of New York City.

T. F. Barton (A'12, F'30) district engineer, General Electric Company, New York, N. Y., is junior past-chairman, and for the year 1933–34 an ex-officio member of the executive committee, of the Institute's New York Section.

R. C. Scott (A'23, M'31) formerly an electrical engineer with the Stone and Webster Engineering Corp., at Boston, Mass., is now electrical engineer for The Mutual Boiler Insurance Company, Boston.

C. R. Beardsley (A'08, F'30) assistant superintendent of distribution, Brooklyn Edison Company, has been elected secretary-treasurer of the Institutes New York Section for the year 1933–34.

Obituary

Fredrick Leland Rhodes (A'03, M'12, F'13) who, at the time of his retirement in March 1932, was outside plant development engineer, American Telephone and Telegraph Company, New York, N. Y., died March 18, 1933, at his home in Short Hills, N. J. He was born in Boston, Mass., in 1870, and received the degree of B.S. in E.E. from Massachusetts Institute of Technology, Cambridge, Mass., in 1892. From that year until his retirement, Mr. Rhodes was a member of the organization of the American Telephone and Telegraph Company, and its predecessor, the American Bell Telephone Company. He entered the mechanical department of the American Bell Telephone Company of Boston, Mass., in 1892, and for several years was occupied chiefly in electrical measurement work relating to telephone transmission over open wire lines and cables, and with the design and development of induction and repeating coils. In 1899 when this department was amalgamated with the engineering department of the American Telephone and Telegraph Company, he began to specialize in the design and engineering of the outside plant of the telephone system, and in 1905 was placed in charge of the division of the engineering department of this company responsible for the outside plant engineering. This work consisted in fixing the standards of outside plant for the Bell system throughout the United States, and supervising the development of new apparatus and methods for use in the outside plant. He frequently had given expert testimony in legal cases, both in the United States and in Canada. In 1919 he was transferred from the position of outside plant engineer to that of outside plant development engineer. He was one of those who in 1912 accompanied the late Gen. J. J. Carty to the Pacific Coast on a trip which resulted in 1915 in the completion of the transcontinental telephone line which made possible the first speech transmission between the Atlantic and the Pacific coasts and led to the extension of nation-wide telephone service. He travelled extensively throughout the country from 1912 to 1928, supervising on the scene and from his home office the installation of many improvements. Mr. Rhodes made a close study of the history of telephony, both technical and legal. In 1929, he published "The Beginnings of Telephony," which is regarded as one of the most complete and authoritative histories of the legal controversy which raged about the invention of the telephone. Just before his retirement, Mr. Rhodes completed a biography of General Carty which was issued privately in 1932 under the title "John J. Carty—An Appreciation." Mr. Rhodes took a keen interest in the civic affairs in Short Hills, and for many years was a director of the Short Hills Association. He was a member of the Short Hills Club, and the Governor Dudley Association, composed of Governor Dudley's descendants. Mr. Rhodes was an active member of the American Standards Association and the American Association for the Advancement of Science, and had served actively on the committees of the National Electric Light Association and the American Electric Railway Association. For the A.I.E.E., Mr. Rhodes served on the board of examiners 1915–20 (chairman, 1918–20), the meetings and papers (now technical program) committee 1916–17, the telegraphy and telephony (now communication) committee 1914–17 (chairman 1915–17), and the standards committee 1922–31. He was the author of many scientific papers on telephony, some of which appeared in the Bell Telephone Quarterly, and articles on telephony in Nelson's Loose Leaf Encyclopedia, the Encyclopedia Americana, and the supplement of the Encyclopedia Britannica. He was the author of several papers presented before the Institute.

Alphonse L. Drum (A'11, F'13) former president of the Eastern Michigan Railways, Eastern Michigan Motor Buses, and other transportation companies making up the Eastern Michigan System, died March 17, 1933, at Detroit, Mich. He was born in San Francisco, Calif., in 1875. In 1896 he graduated from Massachusetts Institute of Technology, Cambridge, Mass., with the degree of B.S. in E.E. From 1896 to 1898 he was successively electrical engineer for the Boston Electric Light Company, the Suburban Light and Power Company of Boston, and the Middleboro Gas and Electric Company, Middleboro, Mass. From 1898 to 1901, he was manager of railway and lighting properties for Stone and Webster, Boston, Mass. During 1902 and 1904 he was general manager and constructing engineer for the Indiana Union Traction Company and other railway properties in that part of the country. In 1905, he was general manager and constructing engineer for the Chicago and Milwaukee Electric Railroad Company. In 1906, he undertook a consulting and constructing engineering practice in Chicago, Ill., and remained active in this work for many years. During the World War he was a consulting expert to the United States Shipping Board and the United States Housing Corporation. In 1925, Mr. Drum went to Detroit, Mich., to make a survey for the receivers for the Detroit United Railways, and remained to head the Eastern Michigan Railways, which succeeded the Detroit United Railways.

William James Harvie (A'03) electrical railway engineer, Albany, N. Y., died March 22, 1933, at Richmondville, N. Y., where he had been supervising the construction of Richmondville's new Central School. He was formerly chief engineer and general manager of traction companies in central New York for more than 20 years, and was the builder of the third-rail line between Syracuse and Utica, N. Y. He was born in 1875 in Buffalo, N. Y., and in 1900 graduated from Syracuse University with an electrical engineering degree. During the $2^1/_2$ years following graduation he was successively in the operating department of the Western Union Telegraph Company, Buffalo, N. Y., in the overhead department of the Syracuse Rapid Transit Railway Company, Syracuse, N. Y., with the Syracuse Lakeside and Baldwinsville Railroad Company, Syracuse, N. Y., in charge of the car house and power house for the Syracuse and Suburban Railroad at Manlius, N. Y., and in charge of the electrical department of the Lakeside and Baldwinville Railroads. In the latter part of 1902, he joined the organization of the Utica and Mohawk Valley Railroad Company, first on construction, and then as electrical engineer. In 1908, Mr. Harvie became chief engineer of the Syracuse Rapid Transit and the Oneida Railway Company, retaining supervision of the Utica properties. In 1912 he resigned to become railway manager for the operating department of the J. G. White Company of New York, N. Y., and was later chief engineer of Allen and Peck, Inc., New York, N. Y. In 1916 he returned to Syracuse as president and general manager of the Syracuse and Suburban Railway Company, and a few years later became vice-president and general manager of the Auburn and Syracuse Electric Railway Company, resigning in 1923. Five years ago he went to Albany as director of personnel for the United Traction Company, and subsequently became associated with the state education department having charge of the construction of school buildings. He had been active in state and national electric railway associations, and in 1910 was president of the American Electric Railway Engineers Association.

Alfred Fellows Masury (M'23) vice-president, chief engineer, and director of the Mack International Motor Truck Corporation, New York, N. Y., died April 4, 1933. He was a guest passenger on the U. S. S. "Akron" and was killed in the crash of that dirigible. Deeply interested in aeronautics, he was a lighter-than-air enthusiast and had previously flown thousands of miles in all kinds and types of this craft. He was aboard the Graf Zeppelin on its attempted westward transatlantic flight in May 1929, which nearly ended disastrously. He was born in Danvers, Mass., in 1882, and graduated in 1904 from Brown University, Providence, R. I., with a mechanical engineering degree. Subsequently he attended night courses at Columbia University. Between 1904 and 1906, he was with the General Electric Company at Lynn, Mass., engaged in the design of 5,000 and 8,000 Curtis generators, and for the following year was with the Vaughn Machine Company, Peabody, Mass., engaged in drafting and design of gasoline and electric automobiles. Between 1907 and 1912 he was chief engineer and general manager of the Hewitt Motor Company, New York, N. Y., and was concerned principally with electric ignition and similar problems in the manufacture of Hewitt trucks. In 1912 he became vice-president, chief engineer, and director of the International Motor Company, later the Mack International Truck Corporation, New York. In this position he was active in the development of equipment for starting, lighting, and ignition, magnetos, search-

light trucks for the engineer division of the U.S. Army, stationary generator sets, welding sets on trucks, heat treating by electricity at plants, etc. During and after the war he worked in an advisory capacity for the Army Ordnance Department, chiefly in connection with automotive equipment and transportation. He held the rank of lieutenant-colonel in the reserves of the U.S. Army. He was a member of The American Society of Mechanical Engineers, the American Society of Civil Engineers, the Institute of Automotive Engineers (England), and had been a vice-president and committee member of the Society of Automotive Engineers.

Robert Orsettich (A'09, F'26) chief engineer of the General Electric Company, Ltd., London, England, died recently in that country. He was born in 1876 in Trieste, Austria. After graduating from the Polytechnic School in Vienna with a degree of electrical engineering, he spent one year in a laboratory in Italy. In 1897, he was engaged in the design of electrical equipment for the shipyard of the Austrian Lloyd Company. In 1898, he became electrical engineer in the power and central station department of the Lahmeyer Company, Francfort-on-Main, England, and in 1900 was sent by this company to the Paris Exposition in charge of erection and operating of the plant. In 1901 he became mechanical designer with Siemens and Halske, Berlin, Germany, and in 1902 was electrical designer with Sir W. G. Armstrong Whitworth & Company at Newcastle-on-Tyne, England. In 1903 he became chief electrical designer of the Wilton Works, Birmingham, of the General Electric Company, Ltd. Since 1918 he has been chief engineer of the General Electric Company, Ltd., at London. In this capacity, he had sole charge of all electrical and mechanical designs of all machines manufactured by the company, as well as all inspection and testing. During this period he also had charge of the experimental laboratory, and had been advising the directors on matters of patents and general engineering policy.

Charles Edward Eveleth (A'06) vice-president of the General Electric Company, Schenectady, N. Y., died in that city March 25, 1933, following an illness of several months. Born in India in 1876, he was brought to this country to attend school and graduated from the Worcester Polytechnic Institute, Worcester, Mass., in 1899, with the degree of doctor of engineering. That year he entered the testing department of the General Electric Company at Schenectady and remained with that organization until his death. He was first in the testing department of the company, and then after serving in various engineering departments was made research engineer on submarine work during the war. Upon completion of the war work Mr. Eveleth entered the turbine engineering department and of his 4 years with this department served 2 as executive engineer. In 1922 he was appointed assistant manager of the Schenectady works and in 1923 was made works manager, which position he held until he became a vice-president in 1927. Mr. Eveleth had been president of the board of education of Schenectady, and was a member of the board of various civic organizations. He was a member of the board of trustees of Worcester Polytechnic Institute, and was a member of The American Society of Mechanical Engineers and the American Association for the Advancement of Science.

Arthur H. Savage (A'24) president of the Union Public Service Company, St. Paul, Minn., died recently. The Union Public Service Company, with headquarters at St. Paul, is an operating utility serving a number of towns in southwestern Minnesota and eastern South Dakota. He was born in Stockbridge, Mass., in 1872. Between 1893 and 1899, he was a partner in the electrical contracting firm of W. I. Gray & Company, Minneapolis. From 1893 to 1913, he was northwestern sales agent for the Fort Wayne Electric Works of the General Electric Company, with headquarters in St. Paul. For the following year he was in the sales department of the General Electric Company at Minneapolis. In 1912, he became treasurer and half owner of the Dakota Light and Power Company; in 1920, treasurer and half owner of the Union Public Service Company of Minnesota; and in 1921 president of the Midwest Power Company. He held these positions in these 3 companies for many years. A few years ago he became president of the Union Public Service Company.

John S. Jenks (A'17) vice-president and chief engineer of the West Penn Power Company, Pittsburgh, Pa., died March 16, 1933, at Mount Pocono, Pa. He was born at Pittsburgh, Pa., in 1873, and before joining the organization of the West Penn Power Company in 1902 was in the organization of the Westinghouse Elec. and Mfg. Company at East Pittsburgh. For the West Penn Power Company he held various positions. As transmission engineer he engaged in work involving right-of-way and the engineering, construction, and operation of transmission lines, substations, and power stations. Subsequently he became assistant to the general manager, later assuming supervision of all activities relating to power service, and then undertook new executive duties as vice-president of the company. In 1930 he was elected vice-president and chief engineer of the West Penn Power Company, in charge of the electric properties.

Local Meetings

Schenectady and Pittsfield Sections Hold Competition

Following the plan inaugurated 4 years ago to encourage their younger members to participate in programs, the Pittsfield and Schenectady Sections held joint meetings in Pittsfield, March 28, 1933, and Schenectady April 7, 1933, for the presentation of papers by Section members less than 30 years of age, who had not previously presented Institute papers. The programs were as follows:

Pittsfield

An Indentification Tag for the Airport, by W. P. Simpson, Schenectady

Eddy Currents and Forces in Air Core Reactors, by A. U. Welch, Pittsfield

Panel Heating, by Louis Levine, Schenectady

Electron Tubes as Variable Condensers, by C. W. Lampson, Pittsfield

Control of an Oil Burning Furnace, by A. L. Sweet, Schenectady

Rating the Factory Employee, by W. S. Fielding, Pittsfield.

Schenectady

Progress in Magnetic Steel Research, by Weston Morrill, Pittsfield

Twisting the Tail of a Series Motor, by A. A. Merrill, Schenectady

A New Scheme for Simultaneous Control of Voltage and Power Factor, by F. L. Woods, Pittsfield

New Developments for Improved Selling, by J. F. Carland, Schenectady

A Small High Voltage Substation, by L. W. Foster, Pittsfield

A New Method for Locating Cable Faults, by J. H. Finley, Schenectady

Prizes were awarded after consideration of the contents of the papers as well as the presentation. At the Pittsfield meeting, W. S. Fielding of Pittsfield received the first prize, and C. W. Lampson, Pittsfield, received second prize; the attendance was 180. At the Schenectady meeting Weston Morrill of Pittsfield received the first prize and J. H. Finley of Albany received the second prize; the attendance was 150. The combined prize, the Robert Treat cup, will be in the custody of the Pittsfield Section for one year.

Student Convention at Drexel Institute

The 9th annual local student convention sponsored by the Philadelphia and Lehigh Valley Sections was held at Drexel Institute on March 13, 1933, with 8 schools participating: namely, Delaware, Drexel, Haverford, Lafayette, Lehigh, Pennsylvania, Princeton, and Swarthmore. The program of the morning session was as follows:

Use of the Matrix in the Solution of Problems on 3-Phase Systems by Symmetrical Components, by M. F. Rosol, Univ. of Penn.

The Synchronous-Mechanical Rectifier Inverter, by J. R. Fritz, Lehigh Univ.

Electroplating, by R. T. Johnson, Lafayette Col.

The Development of a Dosage Technique for X-Ray Therapy, by R. W. Deemer, Drexel Inst.

Those attending the convention were guests of Drexel Institute at luncheon. Inspection trips were held. Following dinner at the Engineers' Club, H. P. Charlesworth, president A.I.E.E., assistant chief engineer, American Telephone and Telegraph Company, New York, N. Y., gave an address entitled "New Frontiers Through Research and Engineering." The registration was 175.

Future Section Meetings

Boston

May—Annual dinner and entertainment.

Cleveland

May 18—Annual dinner meeting. Speaker—H. P. Charlesworth, pres., A.I.E.E., vice-pres., Bell Tel. Labs., Inc.

Detroit-Ann Arbor

May 16 at Lansing, Mich. Advances in Lighting, by Prof. H. H. Higbee, Univ. of Mich.
June 17—Annual spring outing.

Fort Wayne

May 16—Electric Refrigeration and Air Conditioning, by Chester Lichtenberg, Genl. Elec. Co.

Lehigh Valley

May 19 at Sterling Hotel, Wilkes-Barre. Modern Industrial Science, by Dean Dexter S. Kimball, Cornell Univ.

Past Section Meetings

Baltimore

The Manufacture of Structural Steel Shapes and Related Specialties, by N. J. Hittinger, Bethlehem Steel Co. Dinner. Feb. 17. Att. 70.
The Contributions of Science to the Medical and Surgical Profession, by Dr. T. S. Cullen, Johns Hopkins Hospital. Moving pictures. Joint meeting with A.S.C.E. Sec. March 10. Att. 95.

Boston

High Tension Fuses, by H. E. Stockwell, Schweitzer & Conrad, Inc., E. A. Williams, Genl. Elec. Co., and Mr. Lingal, Westinghouse Elec. & Mfg. Co. March 14. Att. 125.

Chicago

The Application of Science to Industry, by Dr. F. B. Jewett, pres., Bell Tel. Labs., Inc. Joint meeting with Western Soc. of Engrs. Dinner. March 6. Att. 605.
The Coordination of Insulation for Lightning Protection, by A. C. Monteith, Westinghouse Elec. & Mfg. Co. Illus. Power group. March 14. Att. 65.

Cincinnati

Signal Equipment and Signal Systems for Railways, by H. S. Loomis, Union Switch & Signal Co. Inspection trip through the Cincinnati Union Terminal. March 9. Att. 200.

Columbus

Invisible War on Crime, by C. L. Chafee, Am. Dist. Tel. Co. March 31. Att. 60.

Connecticut

Urban Transportation, by W. T. Rossell, Brooklyn & Queens Transit Corp.; The Persent Transportation Situation, by J. J. Pelley, N. Y., N. H. and H. RR. Joint meeting with A.S.M.E. Sec. and New England St. Ry. Club at New Haven. Feb. 15. Att. 223.
Hot Cathode Rectifiers, by A. W. Hull, Genl. Elec. Co. Meeting at Bridgeport. March 14. Att. 75.

Dallas

Progress Through Research and Engineering, by H. P. Charlesworth, pres., A.I.E.E., vice-pres., Bell Tel. Labs., Inc. Dinner. March 6. Att. 203.

Detroit-Ann Arbor

The Talking Efficiency of Telephone Circuit, by H. S. Osborne, Am. Tel. & Tel. Co. March 21. Att. 130.

Fort Wayne

Some Modern Protective Relays, by V. Verrall, Genl. Elec. Co.; Modern Methods and Equipment for Power Supervision, by B. A. Grimm, Indiana Serv. Corp. Inspection trip through the load dispatching room of the Indiana Serv. Corp. March 14. Att. 45.

Houston

Progress Through Research and Engineering, by H. P. Charlesworth, pres., A.I.E.E., vice-pres., Bell Tel. Labs., Inc. March 10. Att. 200.
Some Economic Considerations of Primary and Secondary Distribution, by D. K. Blake, Genl. Elec. Co. March 24. Att. 44.

Indianapolis-Lafayette

The Engineer and the Economic Unbalance, by Dean A. A. Potter, Purdue Univ., pres. A.S.M.E. Joint meeting with A.S.M.E. Sec. March 24. Att. 176.

Iowa

The Outlook for the Engineering Graduate, by Dean T. R. Agg, Iowa State Col.; Vacuum Tubes and Their Industrial Applications, by E. S. Darlington, Genl. Elec. Co. Dinner. Joint meeting with Iowa State Col. Branch. March 8. Att. 85.

Kansas City

Electrical Distribution and Domestic Load, by D. K. Blake, Genl. Elec. Co. March 13. Att. 78.

Lehigh Valley

Symposium on Automatic Control, by F. L. Stone, Genl. Elec. Co., D. L. Pierce, Westinghouse Elec. & Mfg. Co., and H. B. Chandler, Ohio Brass Co. April 7. Att. 128.

Los Angeles

X-Rays, by Prof. C. C. Lauritsen, Calif. Inst. of Tech. Dinner. March 14. Att. 65.
An Experimental Study of Series Modulation, by J. H. Ganzenhuber, student, Univ. of Southern Calif.; Tests of a Capacity Motor, by R. R. Moore and G. O. Pierce, students, Univ. of So. Calif.; Amplifier Efficiencies at High Frequencies, by C. D. Perrine, Jr.; student, Calif. Inst. of Tech.; Characteristics of A-C Arcs at Low Pressures, by J. D. Cobine, student, Calif. Inst. of Tech.; A New Design for a Cathode Ray Oscillograph, by J. G. Pleasants, student, Calif. Inst. of Tech. Joint meeting with Univ. of So. Calif. and Calif. Inst. of Tech. student Branches. Dinner. April 4. Att. 163.

Madison

Electric Propulsion of Ships, by F. D. Mackie, student; The St. Lawrence Waterway and Power Controversy, by J. Schneller, student. Joint meeting with the Univ. of Wis. Branch. Feb. 16. Att. 66.

Memphis

Progress Through Research and Engineering, by H. P. Charlesworth, pres., A.I.E.E., vice-pres., Bell Tel. Labs., Inc. March 3. Att. 42.

Mexico

The Determination of Correctness of Watt-Hour Meter Connections, by G. S. MacLaughlin, Cia. Hidro-electrica Guanajuatense. Illus. March 23. Att. 38.

Niagara Frontier

All the Kings Horses and All the Kings Men, by Paul Cohen, Franchot, Runnals, Cohen, Taylor & Reichert. Dinner. March 17. Att. 60.
Nominating Committee meeting. March 27. Att. 6.

North Carolina

Joint meeting with Duke Univ. Branch. April 7. See report in Branch meetings.

Oklahoma City

Progress Through Research and Engineering, by H. P. Charlesworth, pres., A.I.E.E., vice-pres., Bell Tel. Labs., Inc. Dinner. Feb. 20. Att. 225.

Some Economic Considerations of Primary and Secondary System Design, by George Pingree, Genl. Elec. Co. March 17. Att. 75.

Philadelphia

New Frontiers Through Research and Engineering, by H. P. Charlesworth, pres., A.I.E.E., vice-pres., BellTel. Labs., Inc. March 13. Att. 175.

Pittsburgh

The Coordination and Protection of Insulation, by W. W. Lewis, Genl. Elec. Co. Feb. 14. Att. 88.
The Hoover Dam Project, by Ellwood Mead, Bureau of Reclamation, Dept. of the Interior. March 14. Att. 962.

Portland

What Is the Future of Electricity? by Prof. F. O. McMillan, Oregon St. Col. March 28. Att. 58.

Rochester

John C. Herber, Bell Tel. Labs., Inc., H. J. Klumb, Rochester Gas & Elec. Corp., Ray H. Manson, Stromberg Carlson Tel. Mfg. Co., and H. E. Gordon, Rochester Tel. Corp., gave talks concerning the new broadcasting station WHAM. Joint meeting with I.R.E. and Rochester Engg. Soc. March 2. Att. 150.

St. Louis

Some Economic Considerations of Primary and Secondary Distribution Design, by L. F. Woolston, Genl. Elec. Co. March 15. Att. 50.

San Antonio

Progress Through Research and Engineering, by H. P. Charlesworth, pres., A.I.E.E., vice-pres., Bell Tel. Labs., Inc. March 8. Att. 104.
Distribution System Economics, by D. K. Blake, Genl. Elec. Co. March 22. Att. 49.

San Francisco

Electrons in Metals, by Prof. R. B. Brode, Univ. of Calif. Feb. 24. Att. 106.
Electromagnetic Phenomena in the Atmosphere of Stars and Planets, by Dr. J. A. Anderson, Mt. Wilson Observatory. Dinner. March 24. Att. 95.

Saskatchewan

Exploratory Work in Northern Saskatchewan During 1920 and 1921, by A. C. Garner, chief surveyor, Province of Sask. Feb. 24. Att. 17.

Schenectady

The Work of the N. Y. State Legislature as Seen Through the Eyes of Its Sole Engineer Member, by Senator T. C. Desmond. March 16. Att. 100.
The Engineer's Rôle in the Recovery, by Dean A. A. Potter, Purdue Univ., pres. A.S.M.E. Joint meeting with A.S.M.E. Sec. Dinner. March 20. Att. 120.

Sharon

World Wide Telephony, by Dr. H. S. Osborne, Amer. Tel. & Tel. Co. Film—"An Island Tour." March 20. Att. 144.

Southern Virginia

Joint meeting with State Sections of A.S.C.E., A.S.M.E., and Engrs.' Club of Hampton Roads. State Engineering Councils, by Prof. A. F. Macconochie, Univ. of Va.; The Engineering Outlook, by Prof. W. S. Rodman, Univ. of Va. Motor bus trip and dinner. Internal Combustion Engines, by W. H. Butler, Standard Oil Co. of N. J.; New Tools for the New Age, by C. M. Ripley, Genl. Elec. Co. March 3. Att. 110.

Spokane

Executive Committee meeting. Jan. 13. Att. 7.
Demonstration of glass bending and the manufacture of neon signs. Dec. 9. Att. 12.
Inspection of equipment of radio station KHQ. Explanation of operation by A. G. Sparling. Feb. 3. Att. 10.
Dean H. V. Carpenter, State Col. of Wash., outlined the work being done by the Engg. Experiment Station at the State Col. of Wash. March 24. Att. 20.

Springfield

Aeronautical and Police Radio Equipment, by D. G. Little, Westinghouse Elec. & Mfg. Co. March 13. Att. 125.

Syracuse

Submarine Treasure Hunting With Underwater Lamps, by E. W. Begg, Westinghouse Lamp Co. Feb. 27. Att. 322.

ADVENTURES IN ENGINEERING, by Crosby Field. March 20. Att. 187.

Toledo

HUMANOCRACY, by R. C. Dunn; AIMS OF THE AFFILIATED SOCIETY, by J. A. Dinwiddie, Westinghouse Elec. & Mfg. Co. March 3. Att. 40.

Executive Committee meeting. March 8. Att. 7.

PRINCIPALS OF ALTERNATING CURRENT, by J. H. Hunt, Toledo Edison Co. G. E. Hardy, chmn., Ohio Waterways Committee of the Great Lakes Tidewater Assn., described the waterway system. March 17. Att. 49.

Toronto

ELECTRICAL FEATURES OF THE CHATS FALLS DEVELOPMENT AND THE TRANSFORMER STATION, by G. E. Kewin, Hydro-Electric Pwr. Comm. March 10. Att. 67.

LOAD BUILDING WITH ELECTRIC BOILERS AND FURNACES, by R. W. Leeper and J. S. Keenan, Canadian Genl. Elec. Co. Illus. March 24. Att. 75.

AIR CONDITIONING, by F. C. Lyons, Frigidaire Corp. April 7. Att. 65.

Utah

Annual dinner dance. Feb. 13. Att. 70.

ELECTRICITY FOR HEALTH AND COMFORT IN THE HOME, by H. T. Plumb, Genl. Elec. Co. March 20. Att. 53.

Vancouver

RECENT DEVELOPMENTS IN X-RAY APPARATUS, by C. McKenzie, Victor X-Ray Co. Oct. 3. Att. 52.

EXPERIENCES OF AN EXECUTIVE ENGINEER IN PUBLIC PRACTICE, by A. J. Smith. Nov. 7. Att. 27.

CALIBRATION OF CURRENT TRANSFORMERS, by F. L. Bartholomew, Electrical Pwr. Equip. Co., and L. B. Stacey, Packard Elec. Co. Dec. 5, Att. 38.

SINGLE CORE EXTRA HIGH TENSION LEAD COVERED CABLES, by Prof. W. B. Coulthard, Univ. of British Columbia. Jan. 9. Att. 36.

A REVIEW OF RECENT ADVANCES IN PHYSICS AND THEIR APPLICATION TO MODERN ENGINEERING, by Prof. Shrum, Univ. of British Columbia. Feb. 6. Att. 73.

Washington

THE THREE SOURCES OF ELECTRIC POWER FOR THE DISTRICT OF COLUMBIA, by J. H. Ferry, W. J. Lank, and D. C. Vaughan, Potomac Elec. Pwr. Co. Dinner. March 14. Att. 250.

Past Branch Meetings

University of Alabama

Business meeting. March 12. Att. 26.

Mr. Thornton, Alabama Pwr. Co. entertained with a lighting display. Motion pictures. March 17. Att. 210.

University of Arkansas

TECHNOCRACY, by B. Robinson; LIFE OF GEORGE WESTINGHOUSE, by H. Dover; HISTORY AND DEVELOPMENT OF TELEVISION, by Prof. A. S. Brown. March 30. Att. 26.

Armour Institute of Technology

Motion pictures. Feb. 24. Att. 131.

Social affair. March 2. Att. 42.

ALTERNATING CURRENT NETWORKS, by H. E. Wulfing, Commonwealth Edison Co. March 17. Att. 24.

Polytechnic Institute of Brooklyn

APPLICATIONS OF THE THYRATRON TUBE, by J. Sleys; MERCURIC ARC RECTIFIER, by R. Lance; SYNCHRONOUS MOTOR, by F. Stehlick, students. March 1. Att. 42.

A METHOD OF TESTING MODERN RADIO RECEIVERS, by B. Blum; TESTING PHONOGRAPH PICKUPS, by H. Sussmann; COLD LIGHT, by I. Andreason, students. March 9. Att. 37.

Bucknell University

EFFECTS OF ELECTRIC SHOCK, by Dr. W. B. Kouwenhoven, vice-pres., A.I.E.E., Johns Hopkins Univ. Dec. 2. Att. 50.

A STUDY OF VACUUM TUBES, by S. M. Leavitt; THE THEORY OF RELATIVITY, by F. F. Fairchild, students. March 16. Att. 14.

California Institute of Technology

ALTERNATING CURRENT CALCULATIONS BY THE METHOD OF SYMMETRICAL COMPONENTS, by W. A. Lewis, Westinghouse Elec. & Mfg. Co. March 30. Att. 125.

University of California

THE PROBLEMS OF TALKING PICTURES, by G. Hutchins, student; WORLD COMMUNICATION SYSTEMS OF THE RCA COMMUNICATIONS, by R. R. Beal, RCA Communications, Inc. March 2. Att. 72.

ENGINEERS' DAY. March 10. Att. 2730.

Inspection trip to the new 50,000 watt transmitter of station KPO. March 19. Att. 70.

Lecture and sound pictures describing the inside workings in the production of Lincoln automobiles. March 22. Att. 105.

Inspection trip to the Newark Substation of the Pacific Gas & Elec. Co. March 25. Att. 21.

Executive committee meeting. March 28. Att. 7.

Carnegie Institute of Technology

AUTOMATIC COMBUSTION CONTROL, by S. J. Hyle; INDUSTRIAL TESTING OF D-C MACHINES, by F. V. Giolma, students. March 8. Att. 14.

THE FUTURE OF INDUSTRIAL RESEARCH, by S. M. Kintner, Westinghouse Elec. & Mfg. Co. March 22. Att. 86.

Colorado Agricultural College

Inspection trip to the Valmont plant of the Pub. Serv. Co. of Colo. March 10. Att. 39.

THE HOOVER DAM, by J. E. Warnock, U. S. Bureau of Reclamation. March 13. Att. 21.

Philip Self, student, outlined his work while employed by the Western Electric Co. March 27. Att. 14.

University of Colorado

Motion pictures. Feb. 23. Att. 30.

ELECTRONS IN OVERALLS, by E. S. Darlington, Genl. Elec. Co. March 6. Att. 2000.

Cornell University

CATHODE RAY TUBES IN TELEVISION, by D. A. Edwards; HIGH VACUUM TECHNIQUE, by J. Rosenguez; RAILROAD SIGNALLING PRACTICE, by R. D. Ward, students. March 17. Att. 16.

Duke University

DEVELOPMENTS AND PROGRESS IN ELECTRICAL INDUSTRY IN 1932, by S. F. Bluett; DEVELOPMENTS IN ELECTRICAL MACHINERY, by G. F. Dilworth, students. March 7. Att. 19.

DISCOVERY AND EARLY EXPERIMENTS OF THE PHOTOELECTRIC EFFECT, by H. W. Atkinson; ELECTRICITY AND CHEMISTRY, by J. Bryce, students. March 21. Att. 12.

Business meeting. April 4. Att. 26.

OPERATION OF STORAGE BATTERIES, by J. L. Woodbridge, Elec. Storage Battery Co.; CONDENSERS AS STORAGE BATTERIES, by T. J. Garrett, student, Duke Univ.; LOAD DISPATCHING, DUKE POWER COMPANY'S SYSTEM, by C. M. Schoonover, Duke Pwr. Co. Inspection of Duke University and informal dinner preceded address by W. S. Lee, Duke Pwr. Co., past-president, A.I.E.E., entitled THE ENGINEER'S RELATION TO THE PUBLIC. Joint meeting with No. Car. Sec. April 7. Att. 110.

University of Florida

Motion pictures. March 14. Att. 50.

ELECTRICITY ON THE SUBMARINE, by A. C. Ewert; MAGNETIC CHARACTERISTICS OF FROZEN BEAN SOUP, by R. E. Herrick, students. March 27. Att. 35.

Georgia School of Technology

Inspection trip to plant Atkinson on the Chattahoochee River. March 15. Att. 41.

Harvard University

COSMIC RAYS, by J. C. Street, student. March 9. Att. 26.

University of Iowa

ELECTRIC SYSTEM PLANNING, by W. H. Proescholdt, Iowa Elec. Lt. & Pwr. Co. March 8. Att. 34.

USE OF MODELS IN HYDRAULIC EXPERIMENTS, by M. E. Nelson. March 15. Att. 52.

Motion pictures. March 22. Att. 27.

QUARTZ AND ITS ELECTRICAL PROPERTIES, by J. A. Sayre, student. March 29. Att. 26.

RAILWAY ELECTRIFICATION, by J. E. O'Toole, A. C. Roth, and R. K. Pearson, students. April 5. Att. 33.

University of Kansas

ARC WELDING PROJECTS NOW UNDER CONSTRUCTION, by V. M. Smith; ADVANTAGES OF SHIELDED ARC WELDING PROCESS, by M. R. Simpson, Lincoln Elec. Co. Moving pictures. March 9. Att. 31.

University of Kentucky

Business meeting. Feb. 15. Att. 46.

Inspection trip to the Lexington Telephone Co. March 8. Att. 45.

Lafayette College

CALIBRATION OF ELECTRIC METERS, by J. C. McMackin, Metropolitan Edison Co. March 17. Att. 25.

Lewis Institute

A CENTURY OF PROGRESS, by Capt. Corby. Illustrated. Joint meeting with Western Soc. of Engrs. Jan. 31. Att. 185.

ETHICS AND THE ENGINEER, by A. J. Hammond, pres., A.S.C.E. Joint meeting with Western Soc. of Engrs. Feb. 15. Att. 165.

THE PHOTOELECTRIC CELL, by R. B. Kellogg, Commonwealth Edison Co. Joint meeting with Western Soc. of Engrs. March 2. Att. 175.

INTERESTING EXPERIENCES OF AN ENGINEER, by T. L. Condron, Condron & Post. Joint meeting with Western Soc. of Engrs. March 16. Att. 160.

Marquette University

TRENDS IN PRODUCTION METHODS, by F. P. Reilly, Vilter Mfg. Co. March 9. Att. 16.

Michigan State College

TECHNOCRACY, by Prof. Wm. Haber. March 1. Att. 19.

TELEPHONE CABLES, by A. E. Lewis, Michigan Bell Tel. Co. March 15. Att. 26.

University of Missouri

Discussion. March 14. Att. 22.

Montana State College

THE BACKGROUND OF THE PUBLIC OWNERSHIP CONTROVERSY, by Prof. C. F. Bowman. March 9. Att. 69.

LOGGING IN WESTERN MONTANA, by M. Axelson; VERTICALLY CUT SOUND RECORDS, by J. W. Gilmer; MODERNIZED LOCOMOTIVES, by D. Hyde, students. March 30. Att. 51.

SUPERVISORY SYSTEM CONTROLS PUMP HOUSE, by J. Antonich; A NEW POWER SYSTEM FOR WEST POINT, by C. O. Bergland; A DIRECT READING OHMMETER, by O. Johnston; THE RADIO ROBOT OF THE AIRWAYS, by G. Misevic, students. April 6. Att. 65.

University of Nebraska

ELECTRONS IN OVERALLS, by E. S. Darlington, Genl. Elec. Co. March 7. Att. 110.

IN A TELEPHONE OFFICE, by J. D. Brewer, student. March 22. Att. 12.

University of Nevada

SNOW SURVEY, by J. Shaver, Sierra Pacific Pwr. Co. Moving pictures. March 15. Att. 25.

Newark College of Engineering

HIGH VOLTAGE RECTIFIERS, by A. A. Rosenkrans; GRID CONTROL OF MERCURY ARC RECTIFIERS, by J. G. Woehling; THE JET WAVE RECTIFIER, by L. Kutyniak, students. Feb. 27. Att. 16.

University of New Hampshire

Discussion on shunt and over-compounded generators. Feb. 18. Att. 27.

VISIT TO A COAL MINE IN SCRANTON, by B. H. Booth; FLEMING'S MERCURY ARC, by H. S. Marston. Prof. L. W. Hitchcock, counselor, demonstrated a three-phase induction motor. Feb. 25. Att. 30.

MAGNETIC AND DYNAMIC SPEAKERS, by L. A. Knox; THE THEORY OF FADING, by N. I. Diotte, students. March 4. Att. 23.

Motion pictures. March 11. Att. 30.

University of New Mexico

HIGH FREQUENCY INDUCTION FURNACES AND ALTERNATORS USED WITH THEM, by C. Russell, counselor; IONIZATION CHAMBERS USED IN APPARATUS FOR MEASURING X-RAY INTENSITIES IN "R" UNITS, by Harold Deck, Genl. Elec. Co. March 28. Att. 7.

College of the City of New York

DELAWARE AND LACKAWANNA ELECTRIFICATION by E. L. Moreland, Jackson & Moreland. March 30. Att. 30.

New York University

THYRATRON CONTROL OF ELECTRICAL MACHINERY, by K. Dumond; B SUPPLY FROM AN A

Battery, by F. Halleck; Statistical Methods Applied to Engineering, by W. Ramsey, students. March 10. Att. 21.

Surge Absorbers, by C. Hutchinson; Oil Electric Locomotives, by E. Day, students. March 24. Att. 20.

North Carolina State College

Business meeting. April 4. Att. 45.

University of North Dakota

Progress of Electricity in the Last Year, by G. P. Beck, student. Election of officers: E. P. Dubuque, chmn.; A. E. Russell, vice-chmn.; G. P. Beck, secy. March 1. Att. 21.

Light, by R. B. Witmer, student. March 22. Att. 20.

University of Notre Dame

Electric Interurban Railroads, by C. H. Jones, South Shore Line; Magnetism and Magnetic Materials, by J. Quinn, student; Modern Lighting Trends in Architecture, by D. Neale, student. March 13. Att. 50.

The World of Tomorrow, by O. P. Cleaver, Westinghouse Elec. & Mfg. Co. Illus. March 29. Att. 70.

Chain Broadcasting, by J. T. Jenkins, Amer. Tel. & Tel. Co. Joint meeting with Notre Dame Engrs.' Club. April 5. Att. 90.

Ohio State University

Demonstration of the "Mechanical Man." Nov. 14. Att. 600.

Dinner meeting. Jan. 18. Att. 30.

The Economic Situation of Today, by Dr. Viva Boothe. March 2. Att. 45.

Oklahoma A. & M. College

Gaseous Tube Lighting, by J. Niseheimer; Individual Electric Plants, by M. Cox, students. Feb. 27. Att. 30.

Surge Proof Transformers, by J. R. Jones; Muscle Shoals, by G. Folk, students. March 13. Att. 25.

Oregon State College

Supervisory Control, by V. B. Wilfley and C. C. Boozier, Westinghouse Elec. & Mfg. Co. March 14. Att. 64.

University of Porto Rico

Inspection of the electric plants of the Porto Rico Railway, Light, and Power Co. at Comerio and San Juan; also radio station WKAQ. Feb. 25. Att. 12.

Pratt Institute

The Old and New Theories of Light, by J. E. Thomson. Jan. 10. Att. 98.

Physical Elements of the Universe, by Mr. Hertzler. Illus. Feb. 7. Att. 92.

Princeton University

A New Type of Frequency Meter, by C. W. Morehead. March 20. Att. 12.

Purdue University

R. M. Booth, R. C. Brewer, R. J. McMahan, C. Caldwell, and M. W. Baird, students, gave talks describing radio station W9YB. March 23. Att. 60.

Rensselaer Polytechnic Institute

History ahd Development of the Nickel and Associated Industries, by A. J. Wadhams, Intl. Nickel Co. March 21. Att. 175.

Rice Institute

Election of officers: J. D. Hudson, chmn.; H. C. Kriegel, vice-chmn.; E. A. Farris, Jr., secy.; J. F. Anderson, treas. Feb. 17. Att. 13.

John Anderson, student, read a paper published by the Cincinnati Milling Machine Co., concerning the selection of a field of employment and career. March 24. Att. 13.

Rose Polytechnic Institute

Motion pictures. March 16. Att. 32.

Inspection trip to the Dresser Power Plant. March 22. Att. 30.

Propagation Theory of Short Waves, by R. L. Barr; The Near Echoes in Short Radio Waves, by F. M. Anthony, students. April 6. Att. 29.

Inductive Coordination, by Mr. Moore, Indiana Bell Tel. Col. Demonstrations. April 7. Att. 111.

University of South Carolina

Living Germs From Other Worlds, by J. D. Miof; Lightning Protection of Distribution Transformers, by J. D. Martin; Measuring the Temperature of the Stars, by J. T. Lyman, students. March 13. Att. 35.

Mississippi Flood Control, by L. C. Jones, student. Joint meeting with A.S.C.E. Branch. March 27. Att. 60.

Election of officers: C. L. Bradley, pres., D. W. Cardwell, vice-pres.; C. O. Warren, secy.-treas. April 3. Att. 17.

University of South Dakota

The Thyratron Tube, by L. E. Johnson, student. March 8. Att. 13.

Southern Methodist University

The Transmission of High Voltage Direct Current, by S. W. Marshall. April 4. Att. 23.

Stanford University

T. M. Blakeslee, Los Angeles Bureau of Lt. & Pwr., gave a talk concerning a problem which arose on the Los Angeles system dealing with telephone interference from transmission lines. Motion pictures. March 16. Att. 20.

Syracuse University

An Important Phase of the Electrical Field, by E. Pharo; Electrical Precipitation, by P. Nevaldine, students. March 7. Att. 22.

Garden Illumination From Practical Experience, by A. J. Paucek, student. March 14. Att. 23.

Fuses, by John Mayo; Electricity in the Coal Mine, by Wm. Moriarty; Municipal *vs.* Private Owned Power Companies, by C. Middleton, students. March 21. Att. 23.

Texas Technological College

Surface Conductivity in Photoelectric Cells, by A. Waghorne, student. Jan. 10. Att. 18.

Motion pictures. Feb. 1. Att. 15.

A Description of the New Power Installation at the West Point Military Academy, by W. Waggoner, student; The Aims and Accomplishments of the Texas Technological College Alumni Association, by W. E. Street. March 7. Att. 16.

University of Vermont

A Bridge Method of Testing Welds, by W. N. Coburn; A New Rotary Type Voltmeter, by D. C. Whitney, students. Feb. 22. Att. 16.

115 Kv Oil Filled Submarine Cable Which Crosses the Columbia River, by D. C. King; Switchboard Control Devices, by D. W. Jenks, students. March 6. Att. 16.

Virginia Polytechnic Institute

Automatic Railway Signaling, by J. W. Carpenter; The Radio Compass, by T. M. Conte, students. March 9. Att. 29.

Vacuum Tubes, by W. B. Webber; The Power of Water, by A. deVillsante, students. March 23. Att. 26.

Electrical Hoists, by N. C. Smoot; Motor Controllers, by J. S. Jarris, students. March 30. Att. 36.

Mercury-Arc Power Rectifiers, by T. E. Gilhooley; The Evolution of the Transformer, by W. L. Outten; Dynamic Braking of Synchronous Machinery, by M. H. Hudson, students. April 6. Att. 34.

University of Washington

Electrostatic Voltmeter, by Wm. R. Morse, student. Feb. 6. Att. 18.

Inspection trip to the Melrose Telephone Exchange. Feb. 14. Att. 45.

Demonstration of the Barkhausen Effect in the Magnetization Curve, by S. Hansen and G. Barger, students. Feb. 21. Att. 20.

Trolley Wire Lubrication, by J. V. Lamson. Feb. 28. Att. 30.

Reversed Refrigeration in the Heating of Buildings, by R. W. Hutchinson, student. March 7. Att. 15.

Looking Forward, by L. G. Beck, student. April 6. Att. 20.

Washington University

Traffic Problems in Saint Louis, by Charles Gonter. March 7. Att. 24.

Share-the-Work Plans, by Col. McBride, Southwestern Bell Tel. Co. March 14. Att. 20.

Natural Resources, by Dr. J. M. Klamon. April 7. Att. 23.

University of Wisconsin

The Electric Propulsion of Ships, by F. D. Mackie; The St. Lawrence Power and Waterway Project, by J. Schneller, students. Joint meeting with Madison Section. Feb. 15. Att. 66.

A Plan for the Restoration of Employment, by Prof. Edward Bennett. March 16. Att. 43.

Employment Notes

Of the Engineering Societies Employment Service

Positions Open

SUPT. OR GENL. FOREMAN, under 40, for factory making a-c and d-c motors from 1 hp to 500 hp. Must have had experience in responsible charge of this kind of work, with thorough practical knowledge of all machine tools used and principles of motor design. Engrs with only design experience need not apply. Moderate salary to start. Apply by letter. Location, N. J. W-3879.

ENGR, experienced in the manufacture of carbon resistors. Must have had this experience with a co. mfg. such resistors. Apply by letter. Location, East. W-4676

ENGR, experienced in the design and manufacture of (Universal) fractional hp motors for nationally known concern, over 20 yr old. Apply by letter. Location, Middle West. W-4686-C

Men Available

Construction

E.E. GRAD., 30, married. Desires connection with construction, utility. mfg. or industrial concern. Six yr experience testing and designing a-c and d-c motors. Location and salary secondary. Available now. D-944

Design and Development

E.E., 4 yr design and development of elec and mech equip. in the aircraft and automotive field. Also considerable experience in elec communication. Desires connection with mfg. engg or operating concern. References. Available immediately. D-2008

ENGR OR ELECTRICIAN, 26, 5 yr with United Engineers and Constructors, designing protection and metering for pwr projects; controlled construction and installation of switchboard panels and related equipment; 5 yr previous with same co. as electrician. Proficient; running conduit, bending copper, control and switchboard wiring. Can operate station. Speaks German. D-2023

E.E GRAD., 30, married, desires position in design and development of elec heating apparatus and furnaces; 4 yr mech design, 1 yr G.E. test, 3 yr elec furnace design. Available immediately. Location immaterial. D-2066

DESIGN ENGR, B.S. in E.E. Purdue '28. One yr grad. work '33; 4 yr G.E. Co. including test and study course and 3 yr in a-c apparatus design. Also 3 mos. transmission line maintenance before graduation. Amateur radio experience. Desires position in engg, operating or teaching. Available June. Location immaterial. D-2061

INDUCTION MOTOR DESIGNER. Elec designing engr with wide experience in designing all types and sizes of induction motors. For the last 20 yr connected with 2 of the country's leading elec mfrs. Available immediately. D-2069

ENGINEERING SOCIETIES EMPLOYMENT SERVICE

57 Post St.
San Francisco

205 West Wacker Drive
Chicago

31 West 39th St.
New York

MAINTAINED by the national societies of civil, mining, mechanical, and electrical engineers, in cooperation with the Western Society of Engineers, Chicago, and the Engineers' Club of San Francisco. An inquiry addressed to any of the three offices will bring full information concerning the services of this bureau.

Men Available.—Brief announcements will be published without charge, repeated only upon specific request and after one month's interval. Names and records remain on file for three months, renewable upon request. Send announcements direct to Employment Service, 31 West 39th Street, New York, N. Y., to arrive not later than the fifteenth of the month.

Opportunities.—A weekly bulletin of engineering positions open is available to members of the cooperating societies at a subscription of $3 per quarter or $10 per annum, payable in advance.

Voluntary Contributions.—Members benefiting through this service are invited to assist in its furtherance by personal contributions made within 30 days after placement on the basis of 1.5 per cent of the first year's salary.

Answers to Announcements.—Address the key number indicated in each case and mail to the New York office, with an extra three-cent stamp enclosed for forwarding.

Executives

THOROUGH DECISIVE, RESPONSIBLE YOUNG MAN wishes position as asst. to a busy man or in a small firm. Good letter writer. Capable of handling much detail accurately and swiftly. Cornell grad. (1927 E.E.). Experience includes newspaper reporting, elec testing, material inspection, correspondence, reports, specification writing. D-2003

THEATRE SPECIALIST illumination design alteration. Professional engr with 15 yr practical, 15 yr contracting, 10 yr consulting. Construction and contracting covered eastern states and Canada including theatres and general construction. Consulting covered this country coast to coast reaching also France and England, specializing in theatres and including general kindred lines. D-2007

ELEC-MECH. ENGR; univ. grad., married, 34; 4 yr steel mills, one yr G. E. test, 3 yr public utility, 4 yr industrials. Estimates, designs, specifications, developments, tests, construction, supervision. Steam hydraulic power plants, manual automatic substations, converter stations, industrial buildings, overhead underground transmission systems, high low voltage equipment. Available immediately. C-2902.

ENGR competent to install coil-winding departments. Is familiar with all coil-winding machine patents. Has designed winding machines for high-speed production. Has served as elec development engr, production engr, and consulting engr on sales, as well as chief engr. Familiar with high-frequency apparatus, electromagnetic devices, transformers, etc. B-6008

GRAD. E.E., 33, single, B.S. in E.E. 9 yr of design and construction of pwr transmission lines, substations and distribution networks as engg inspector, purchasing, expediter, preparing estimates and writing specifications. Excellent references. Desires connection with holding co., operating co., contractor or mfr. Available immediately. Location immaterial. C-3564

GRAD. ENGR, 25 yr broad experience on pwr. plants and ships. Includes design, construction, investigations, reports, patents, supervision, and consulting work. Specialist on high tension transmission lines. Experience in elec, mech., civil and naval architectural fields. New York State prof. engr license. Best references. Available immediately. Location immaterial. C-5824

GRAD. ENGR, B.S. in E.E., single, 28, 3 yr utility experience, Middle West, 2 yr utility, Germany. Operating, design, testing, rate, research. Location immaterial. Will consider representation abroad. Available now. D-2058

Instruction

B.S. in E.E. and E.E., Univ. of Colo., 42, 6 yr teaching E.E., 1 yr acting head E.E. dept., state school. Experience utilities, Westinghouse, etc. Desires position teaching E.E. C-5021

GRAD. E.E. of Ohio Univ., completing requirements for B.S. Ed., Ohio State Univ. Will be eligible for administering instruction in E.E. or as a teacher of mathematics, physics, chemistry, industrial engg in any junior or senior high school for the coming school year. D-1280

ASST. PROF., B.S. (E.E.) and E.E., 34, married, good health, conscientious worker. Three yr G.E. test and engr dept., 5 yr utility, 5 yr teaching with some executive experience. Now employed but change is indicated. Desires position teaching E.E. Available summer, fall. Location immaterial, South, Middle West preferred. Excellent references. Correspondence invited. C-7152

B.S. in E.E., 33, married, 10 yr practical experience in sales and development engg. Entering teaching profession. Now student in school of education, Rutgers Univ. Available June or Sept. 1933 to teach in mathematical, physical, or E.E. lines. Location immaterial. B-9863

TEACHER OF E.E., 30, B.S. in E.E. in 1924. Work almost completed for M.S. Five yr experience in testing, operation, and distribution engg. Last 4 yr instructor in E.E. at engg col. of a state univ. Desires teaching or engg position. Available July 1. Location immaterial. C-1209

ANY WORK for which qualified with utility co. by former engg prof., having 12 yr engg teaching experience in prominent universities. Assoc. engr with Bureau of Standards; executive office work in industrial and in govt. offices. Would like connection with gas or elec utility needing reliable man for investigation work. C-6733

INSTRUCTOR OR ASST. PROF., 38, 8 yr instructor in E.E., radio, physics in important universities; 5 yr commercial experience, ltg., pwr., radio installations, research and design. Available for next Sept. C-6302

E.E. Teaching experience, also 7 yr experience with elec mfg. concern. Can be available next school season. D-2060

B.S. in E.E., 1926; M.S., 1933, physics major, 28. 4½ yr with Westinghouse Elec & Mfg. Co. including 2 yr. experimental and development work on industrial electronic tube devices. Now grad. asst. in physics, serving as lab. instructor. Assoc. Sigma Xi. Desires work as instructor in physics or E.E. C-8888

Junior Engineers

B.S. in E.E., 1932, 26, single. High scholastic record. Good health, good character, and willing to work hard. Desires any kind of engg connection. Some experience in elec drafting, selling, and teaching. Salary of secondary importance. D-1994

B.S. in E.E., Purdue, 1932, 24, single. Tau Beta Pi. Experience: 6 mos. automatic carbon arc welding development, 1 yr in Mich. utility meter dept, 2 yr marine and broadcast radio operator. Would like position with utility or with mfr. of electron tubes or associated apparatus in Middle West. D-2018

E.E. GRAD., Purdue, 1930. Single, 25. Two yr communication experience and training with Am. Tel. & Tel. Co., including outside line and cable construction; testroom operation, carrier systems, etc., also Morse telegraphy. Not afraid of hard work. References gladly furnished. Available immediately to go anywhere. D-1075

E.E., 22, B.S.-E.E., 1930. Desires connection with utility, elec or radio mfg. co. G.E. test experience; 6 mos. work with vacuum tubes. Experience with large motors. Location immaterial. C-9806

B.S. in E.E., 1932, single, 21. Gained experience in elec instrument plant during cooperative course. Desires any position for experience. Salary secondary. D-1578

RENS. POLY. INST. GRAD., E.E., 1932, 22, single. Sigma Xi. Wants job in any elec field. Available now. D-1716

E.E. and M.E. GRAD., single, 26, 4 yr industrial experience in elec line. Location and salary immaterial. Available at once. D-572

B.S. E.E. 1933, Purdue Univ. Honor student, very industrious and energetic, and willing to tackle any kind of work. Experience in elec wiring, and radio work of all sorts. Eta Kappa Nu. Have had work in civil engg, transit, etc. Unmarried. The best of references. Salary and location immaterial. D-2047

E.E., Univ. of Ill. '31, 26, single. Three yr tech. experience including pwr. and telephone engg, Westinghouse test and experimental work, and experience with temperature control apparatus, fan and shading-ring motor design. Knowledge of French and German. Location immaterial. D-1936

Maintenance and Operation

PWR. PLANT AND MAINTENANCE ENGR, extensive experience in switchboard, control equipment and operation and general maintenance in large manufacturing concern. Two yr as electrician, 2½ yr as pwr. house operator and genl. maintenance. Able to assume responsibility. Salary secondary to future. Consider anything. D-2011

COMMUNICATION ENGR, col. grad., 35, single. Nine yr with operating telephone companies, 3 yr telephone engg ry. having extensive long distance telephone system. Thoroughly familiar telephone repeaters, telegraph equip., teletypes. Wide experience transmission and inductive interference problems. D-2027

GRAD. E.E., 29 married. Two yr experience in valuation and inventory of utility; 2 yr as operator at radio transmitting station. Desires position with utility, engg or construction firm. Location immaterial. Available immediately. C-4865-88-C-5-San Francisco.

E.E. GRAD., 26, married, 1 yr Westinghouse test course, 3½ yr with large engg corp.; pwr. plant and substation design and layout, contact man with elec mfrs., extensive industrial engg work. Qualified to investigate and report on new mach. Excellent references. Location immaterial. C-4303

Research

E.E (E.E. deg.), with varied experience in research and executive fields and possessive of initiative, aptitude, youth and common sense, would welcome an opportunity to cooperate on worthwhile endeavor. Location and salary open. Testimonials of competence available from each of former employers. D-1804

Sales

ENGG SALES EXEC., elec-mech. engr, nonferrous metallurgical knowledge. Post grad. deg. Four yr steam, elec RR. experience. Five yr sales experience, dist. engr, mfr. wire, insulated cable covering investigation, analysis, sales of overhead, underground transmission conductors, related products. Acquainted, utilities, industrials, Ill. to Utah. 32, married. Available. D-1923

SALES ENGR, E.E. deg., 31, single. 3½ yr high grade sales experience selling mfrs., industrials and educational institutions, contacting distributors' branches, etc. Excellent correspondent. Several yr engg dept. large utility, also several yr elec testing, Underwriters' Lab.; some elec contracting. Interested, desirable opening anywhere. Moderate remuneration. Available immediately. D-1344

SALES ENGR, 30, single. E.E. grad. midwestern school. Services valuable to utility or mfg. co. desiring man with ability and experience in operation, installation, sales and service of elec machy. Also knowledge of air-conditioning and ventilation. Six yr sales experience in southeast with elec mfr. References. Location immaterial. D-2062

Testing

EXPERT METER MAN, 27, married, 10 yr experience with utilities and private concerns. Last position held 5 yr as chief tester. Location of position open. D-2031

Membership

Applications for Election

Applications have been received at headquarters from the following candidates for election to membership in the Institute. Unless otherwise indicated, the applicant has applied for admission as an Associate. If the applicant has applied for direct admission to a grade higher than Associate, the grade follows immediately after the name. Any member objecting to the election of any of these candidates should so inform the acting national secretary before May 31, 1933.

Bassett, H. B., The Acme Wire Co., New Haven, Conn.

Bolster, W., United Fruit Co., N. Y. City.
Cherry, N. J., 216 St. James Pl., Bklyn., N. Y.
Chiarello, D. M. (Member), Bklyn. Tech. H. S., Bklyn., N. Y.
Cook, J. B., Reliable Elec. Co., Chicago, Ill.
Dalziel, C. F., Univ. of Calif., Berkeley.
Davis, G. H., Conn. Lt. & Pwr. Co., Waterbury.
Georgiev, A., 14 Prospect Park, S. W., Bklyn., N. Y.
Helber, F. E., Route 9, Box 675, Portland, Ore.
Henderson, G. G., 1722 West 37 Ave., Vancouver, B. C., Can.
Herbold, C. F., 1611 Elbur Ave., Lakewood, Ohio.
Jordan, H. G. (Member), Am. Tel. & Tel. Co., N. Y. City.
Kattenhorn, A. W., Am. Tel. & Tel. Co., N. Y. City.
Lovelace, C. K., Okla. Gas & Elec. Co., Enid.
Mackereth, E., Moloney Elec. Co., Toronto, Ont., Can.
Maki, G. J., 433 Charles Ave., S. E., Grand Rapids, Mich.
Milliken, E. L., 142 Kenyon St., Hartford, Conn.
Mills, R. V., 420 W. 119 St., N. Y. City.
Noyes, F. B., The Pacific Tel. & Tel. Co., San Francisco, Calif.
Poitras, E. J., Genl. Elec. Co., Phila., Pa.
Rankin, R. A. (Member), 2039 Mansfield St., Montreal, P. Q., Can.
Rodgers, J., Bklyn. Edison Co., Bklyn., N. Y.
Taylor, F. S., 3219 Octavia St., San Francisco, Calif.
Tefel, A., c/o Capitol Theatre, N. Y. City.
Thorburn, E. D., 1263 40th Ave., San Francisco, Calif.
Thorpe, L. W., 456 E. Wash. St., Sunnyvale, Calif.
Wolff, W. L., Texas-La. Pwr. Co., Winchester, Ky.
27 Domestic

Foreign

Abideen, S., Pub. Wks. Dept., Central Provinces, India.
Akre, E. O., Mexican Lt. & Pwr. Co., Mexico City, D. F., Mexico.
Barker, H., Fabrica "San Jose de la Montana," Queretaro, Qro. Mexico.
Champion, C. H. (Fellow), Charles H. Champion & Co., Ltd.; Ship Carbon Co. of Great Britain, Ltd., London, W. 1, Eng.
Cuneo, E. W., Calle San Nicolas No. 24 Pergamino, Argentina, S. A.
Dave, B. B. (Member), Gujarat Ginning Mills, Post Ry. Pira, Ahmedabad, India.
El-Deen, S. M., Metro-Vickers Co., Ltd., Trafford Park, Manchester, Eng.
Mirikin, I., Palestine Elec. Co., Ltd., Tel. Aviv, Palestine.
Miyata, H., 817 Sheridan St., Honolulu, Hawaii.
Moorman, H. R., c/o Lage Petroleum Corp., Maracaibo, Venezuela, S. A.
Prache, P. M., Forges et Ateliers de Constructions Electriques Jeumont, Nord, France.
Saldana, A. E., Cia Colombiana de Electricidad, Apartado No. 739, Barranquilla, Columbia, S. A.
Simonsen, O., Box 466, Ancon, Canal Zone.
Singh, G., Gurbaksh Singh & Co., Dehradun, U. P., India.
Singh, L. (Member), Punjab Pub. Wks. Dept., Batala City, Punjab, India.
Skerrett, H. R., 10 Hernandez St., Santurce, Puerto Rico.
Sorabji, R., 375 De Lisle Rd., P. O. Jacob Circle, Bombay, India.
Varma, R. D., c/o Siemens-Schuckertwerke, A. U. 2 Berlin, Siemensstadt, Germany.
Widgery, R. G. (Member), Kingston-upon-Thames Corp., Kingston-on Thames, Surrey, Eng.
Yancey, L. C., Chiriqui Land Co., Puerto Armuelles, Rep. de Panama.
20 Foreign

Addresses Wanted

A list of members whose mail has been returned by the postal authorities is given below, with the address as it now appears on the Institute records. Any member knowing of corrections to these addresses will kindly communicate them at once to the office of the secretary at 33 West 39th St., New York, N. Y.

Anderson, Geo. H., 131 Wenonah Road, Longmeadow, Mass.
Bitner, Ralph E., Box 507, Port Washington, L. I., N. Y.
Brobson, John F., Detroit Daily Mirror, Detroit, Mich.
Carroll, J. G., 1537 Walnut St., Kansas City, Mo.
Feldheim, Fred S., Switchgear Engg. Dept., Genl. Elec. Co., Phila., Pa.
Harcus, Wilmore C., United Artists Studio, 1041 N. Formosa Ave., Hollywood, Calif.
Hardey, John Ernest, Box 551, Wellington, N. Z.
Herrington, L. B., Jr., Kentucky Utilities Co., Louisville, Ky.
Jansson, E. O., 53 Ashland St., West Lynn, Mass.
Schlechter, A. H., 103 W. 9th St., Apt. 6, Oklahoma City, Okla.
Tinkey, Otto G., 1401 Albarado Terrace, Los Angeles, Calif.
Tripp, William A., Stone & Webster Engg. Corp., 49 Federal St., Boston, Mass.
Victors, Peter, 420 Presidio Ave., San Francisco, Calif.
Vincent, Henry L., E. 916—19th St., Spokane, Wash.

Engineering Literature

New Books in the Societies Library

Among the new books received at the Engineering Societies Library, New York, during March are the following which have been selected because of their possible interest to the electrical engineer. Unless otherwise specified, books listed have been presented gratis by the publishers. The Institute assumes no responsibility for statements made in the following outlines, information for which is taken from the preface or text of the book in question.

ELEKTROTECHNIK. Einführung in die Starkstromtechnik. Bd. 1. (Sammlung Göschen 196). By I. Herrmann. Berlin & Leipzig, Walter de Gruyter & Co., 1933. 128 p., illus., 6x4 in., cloth, 1.62 rm.—First of 4 volumes which provide a concise course in electrical engineering. This volume is concerned with the physical principles involved, the phenomena of magnetic and electrical fields, and the units of measurement. The treatment is brief, but scientific, and calls for only a limited knowledge of mathematics.

ERDUNG, NULLUNG und SCHUTZSCHALTUNG. By O. Löbl. Berlin, Julius Springer, 1933. 111 p., illus., 9x6 in., cloth, 10.50 rm.—Considerations underlying the rules for the protection of high voltage lines adopted in 1932 by the Soc. of German Elec. Engrs. are discussed in detail. The physiological and engineering principles are explained, and methods of protection considered. The official rules are given, with a commentary.

FAHRZEUGBAU. (Ausgewählte SCHWEISSKONSTRUKTIONEN, Bd. 4.) By E. Kalisch. Berlin, VDI-Verlag, 1933. 90 p., illus., 12x8 in., cloth ($3.00, G. E. Stechert).—An atlas of photographs and drawings, selected by the welding section of the Soc. of German Engrs., to illustrate welding methods used in German factories. The methods given refer to the manufacture of railroad cars, locomotives, airplanes, automobiles, and trucks. Ninety plates, showing over 200 uses, are given.

HIGH SPEED DIESEL ENGINES, with special reference to Automobile and Aircraft Types. By A. W. Judge. N. Y., D. Van Nostrand Co., 1933. 248 p., illus., 9x6 in., cloth, $3.25.—An elementary text for engrs. and students. The theory of the high-speed compression-ignition engine is outlined and its practical aspects are discussed. The design and operation of many types of automobile and aircraft engines are described, with special attention to British practice.

Introduction to INDUSTRIAL MANAGEMENT, Text, Cases and Problems. By E. C. Robbins and F. E. Folts. N. Y. and Lond., McGraw-Hill Book Co., 1933. 356 p., illus., 9x6 in., cloth, $3.00.—A textbook for an introductory course, in which text, cases, and problems are blended in a treatment intended to develop ability to analyze practical problems.

NEW FRONTIERS of PHYSICS. By P. R. Heyl. N. Y. and Lond., D. Appleton, 1930. 170 p., illus., 8x5 in., cloth, $2.00.—An account of recent developments in physics and of the new concepts that have revolutionized that subject in recent years. The book is intended for the general reader without special scientific training.

PROBLEMS in PUBLIC UTILITY ECONOMICS and MANAGEMENT. By C. O. Ruggles. N. Y. and Lond., McGraw-Hill Book Co., 1933. 737 p., illus., 9x6 in., cloth, $6.00.—The case method is applied to the analysis and solution of problems dealing with economic and business aspects of public utilities; 120 problems based on actual cases are discussed. They cover problems of production, management, wholesale and retail marketing, valuation, rate making, regulation, etc.

PUBLIC UTILITY REGULATION. By W. E. Mosher and F. G. Crawford. N. Y. and Lond., Harper & Bros., 1933. 612 p., tables, 9x6 in., cloth, $5.00.—A study of the scope and effectiveness of present methods of regulating public utilities through public service commissions. Stress is laid on administrative aspects of regulation rather than legal and economic ones. Ways in which present powers and methods might be made more effective are indicated.

SHORT WAVE WIRELESS COMMUNICATION. By A. W. Ladner and C. R. Stoner. N. Y., John Wiley & Sons, 1933. 348 p., 9x6 in., cloth, $3.50.—A self-contained presentation of the principles and methods of short wave communication, intended to satisfy the needs not only of engineers and telegraphers but also of amateurs.

STORAGE BATTERIES. By F. B. Crocker, M. Arendt and R. F. Kuns. Chicago, Am. Tech. Soc., 1933. 83 p., illus., 9x6 in., cloth, $1.50.—The fundamental principles of design and manufacture of the various types of storage batteries are clearly and simply presented, after which building and repair are discussed. Attention is given especially to the type of battery used for automobile starting and lighting.

STRENGTH of MATERIALS. By J. P. Kottcamp and A. C. Harper. N. Y., John Wiley & Sons, 1932. 214 p., illus., 8x5 in., cloth, $1.75.—Presents the fundamental principles of the subject with a minimum of mathematics and with the needs of industrial schools in mind. The application of strength of materials in proportioning beams, columns, shafting, and riveted joints, and in problems involving simple stresses is discussed. The new edition has been thoroughly revised and largely rewritten.

TEXTBOOK of PHYSICAL CHEMISTRY, Vol. 1. General Properties of Elements and Compounds. By J. N. Friend. Phila., J. B. Lippincott Co., 1933. 501 p., illus., 9x6 in., cloth.—This volume, the first part of a textbook based upon the work given to senior students at the Birmingham Technical College, deals with the general properties of elements and compounds. The historical development of theories is set forth and their bearing on modern problems indicated.

TELEPHONE THEORY and PRACTICE. 2 v. Automatic Switching and Auxiliary Equipment, 494 p.; Manual Switching and Substation Equipment, 439 p. By K. B. Miller. N. Y. & Lond., McGraw-Hill Book Co., 1933. Illus., 9x6 in., cloth, $5.00.—These volumes continue the treatise on telephony begun in 1930. The volume on manual switching describes the construction and operation of subscriber station equipment and central-office switchboards in manually operated exchanges. The other volume treats of the 4 types of machine switching now in use and also discusses such auxiliary equipment as protective apparatus, distributing frames, power plants, private branch exchanges, and toll switching apparatus.

La TRANSFORMATION de l'ÉNERGIE ÉLECTRIQUE: II. Commutatrices et Redresseurs. By H. Giroz. Paris, Librairie Armand Colin, 1932. 217 p., illus., 7x5 in., paper, 10.50 frs.—A concise theoretical and practical study of rotary converters and mercury arc rectifiers, the major part of the book being devoted to the latter apparatus. The physical phenomena are described, regulation and construction are treated, and the theoretical constants of the different rectifier circuits are conveniently tabulated.

VECTOR ANALYSIS. By H. B. Phillips. N. Y., John Wiley & Sons, 1933. 236 p., illus., 9x6 in., cloth, $2.50. Presents the subject in the form required for work in theoretical electricity and hydrodynamics. The fundamental operations and more general properties of scalar and vector fields are presented, after which the detailed analysis of fields, the properties of potentials and linear vector functions are discussed.

WINDKRAFTWERKE. By H. Honnef. Braunschweig. F. Vieweg & Sohn, 1932. 111 p., illus., 10x6 in., paper, 4.80 rm.—Presents a plan for utilizing wind power for the large scale production of electricity. The scheme contemplates the erection of towers, 600 ft or more high, carrying groups of air turbines. The book describes the calculation and design of the power plant, discusses costs, etc.

Engineering Societies Library

29 West 39th Street, New York, N.Y.

MAINTAINED as a public reference library of engineering and the allied sciences, this library is a cooperative activity of the national societies of civil, electrical, mechanical, and mining engineers.

Resources of the library are available also to those unable to visit it in person. Lists of references, copies or translation of articles, and similar assistance may be obtained upon written application. subject only to charges sufficient to cover the cost of the work required.

A collection of modern technical books is available to any member residing in North America at a rental rate of five cents per day per volume, plus transportation charges.

Many other services are obtainable and an inquiry to the director of the library will bring information concerning them.

Industrial Notes

G-E Develops Oil, Heat-Resisting Cable.—A new cable insulated with Glyptal-treated cloth and capable of resisting oil and withstanding high temperatures has been developed by the General Electric Company and is now available in all types. In addition to its ability to resist oil and heat, this new cable is characterized by unusual flexibility and toughness that enables it to stand severe mechanical strain. The insulating material known as Glyptal is a synthetic resin, produced from phthalic anhydride and glycerine, which is unaffected by mineral oil. Because of this inherent quality, Glyptal-treated cloth has a distinct advantage over varnish-treated cloths as an insulation material. This new cloth also maintains its original properties over long periods of time, even at elevated temperatures. Samples of cable insulated with Glyptal-treated cloth have been exposed to temperatures of 100 degrees C. for periods of three to four months without showing appreciable deterioration. The new cable can be used advantageously for low- and medium-voltage leads, apparatus cable, transformer leads, leads for coils and control devices, or wherever an oil-resisting, heat-resisting cable is required.

Simplex Wire Moves New York Office.—The Simplex Wire & Cable Co., Boston, announces the removal of its New York office to 420 Lexington Ave.

Larger Local Quarters for Line Material Co.—The New York office of the Line Material Co., South Milwaukee, Wis., has been moved to larger quarters at 74 Trinity Place, Room 1014, under the management of Homer Churchill.

A New Nichrome Alloy.—The Driver-Harris Co., Harrison, N. J., announces a new series of "Nichrome" alloys, to be known as "Nichrome" V, the latest step in its development of nickel-chromium alloys. More than 25 years ago the first of the series was produced and the introduction of V has been due to the demand for increased speed, high temperatures, and longer life.

Harnischfeger Appoints New York Agent.—The Florandin Equipment Co., 40 West 40th St., New York, has been appointed metropolitan welder representative by the Harnischfeger Corporation, Milwaukee. Mr. Florandin has been connected with the welding industry for more than twenty years. The full line of modern arc welders, formerly manufactured by the Northwestern Mfg. Co., Milwaukee, is now sold under the trade name P&H-Hansen.

Steel Mill Orders to Westinghouse.—An order for the complete electrification of a new plant near Detroit has been awarded recently to the Westinghouse Electric & Mfg. Co., by the Rotary Electric Steel Co. Among the more important items in this order, which totals $155,000, are 56 motors ranging from 3 to 800 hp, a 10,000 kva electric furnace transformer and control apparatus. The Andrews Steel Co., which is rehabilitating its mill at Newport, Ky., changing from steam to electric drive, has awarded the Westinghouse Co. a $32,000 contract for electric control equipment.

New Fibre Plant Completed.—Taylor & Co., Inc., of Norristown, Pa., manufacturers of vulcanized fibre and phenol fibre announce the completion of their new and modern plant, and the beginning of operations early in May. The company will produce a complete line of vulcanized fibre, fish paper, and laminated phenolic products, including noiseless gears. The executive organization of the company and its entire operating personnel is composed of men formerly associated with the Diamond State Fibre Co., and its subsidiary, The Celeron Co. J. M. Taylor, president, L. T. McCloskey, sales manager, and C. N. Jacobs, plant manager, all held similar positions with the above companies.

New Porcelain Cement.—A practical, liquid, low-cost porcelain cement is the latest development of Henry L. Crowley & Co., ceramic engineers and manufacturers, of West Orange, N. J. It is available in three forms: a paste, a dipping cement, and a dry powder. The cement paste is widely used in electrical production assembly for holding small parts in place, doing away with nuts, screws, and metal solder. The dipping cement is employed for coating electrical resistors and coil forms. Setting in a short time without the application of heat, the cement is said to be proof against oils, acids, gases and heat up to 2000°F. It may be made waterproof and is an excellent electrical insulator.

Trade Literature

Motors.—Bulletin, 4 pp. Describes a new, explosion-proof motor, with two enclosing frames. A large fan is mounted between the frames. The inner frame completely encloses the windings, stator, etc. The outer frame covers and protects the whole unit. U.S. Electrical Mfg. Co., Los Angeles, Cal.

Lugs.—Bulletin, 4 pp. Describes Burndy "Qiklugs," embodying a simple cable clamping principle and requiring only a wrench to make an efficient lug-to-cable connection. Burndy Engineering Co., Inc., 305 East 45th St., New York.

Instrument Fuses.—Bulletin, 8 pp. Describes small fuses, principally from 1/100 to 1 ampere, and mountings, for delicate electrical equipment such as instruments, meters, etc. Littelfuse Laboratories, 1772 Wilson Ave., Chicago, Ill.

Metal Products Manufacture.—Bulletin, 12 pp. Describes and illustrates the facilities and service available for the design, development, and manufacture of all kinds of metal products in any finish—plain, plated, baked enamel, etc. Metal Products Division, Electric Service Supplies Co., 17th & Cambria Sts., Philadelphia, Pa.

Distribution Transformers.—Catalog, 20 pp. Describes a complete line of pole-type distribution transformers, in sizes from $2^1/_2$ to 100 kva. Included also are descriptions and prices on balance coils, balance transformers, primary cutouts, lightning arresters, and oil-test sets. American Transformer Co., 180 Emmet St., Newark, N. J.

Rail Flaw Detector.—Bulletin, 4 pp. entitled "Sperry Detector," occasional issue. Describes four years of progress in rail testing, during which the Sperry Detector cars have tested over 100,000 miles of track on 53 railroads in the United States, Canada, France, and Belgium. More than 14,000 defective rails containing transverse or compound fissures have been marked for removal by the detector cars. Sperry Products, Inc., Manhattan Bridge Plaza, Brooklyn, N. Y.

"Tong-Test" Ammeters.—Bulletins. Describe new "tong-test" ammeters which measure both alternating and direct currents without having to be connected in the circuit and without the need of shunts or ratio transformers. They operate by merely encircling the cable by the trigger operated jaws. Included are heavy current types and accessories such as interchangeable scale-elements, safety insulating pole attachment for high voltage work, and carrying case. Columbia Electric Mfg. Co., 1292 East 53rd St., Cleveland, O.

Overhead Line Construction.—The Copperweld Steel Co., Glassport, Pa., is distributing the first issue of a new publication, "Non-Rusting Copperweld Overhead Line Construction," which will be mailed to engineers connected with power companies, railroads, telephone, and telegraph companies. The initial edition describes and illustrates the guying of a power line along a modern highway; the suspension of two aerial cables from one messenger; a long span river crossing; an unusual guy wire installation and others.

Service Entrance and Drop Cables.—Bulletin, 4 pp. Describes armored service entrance cable, carrying Underwriters approval for service from weatherhead to meter and from meter to range; specially designed for low cost, ease of installation, good appearance and long life. "Amerite" service drop cable is for use from pole to weatherhead; insulated with "Amerite," a performance test, long life rubber compound, protected with non-migrating and alkali resisting ACE tape and weatherproof braid. American Steel & Wire Co., 208 So. La Salle St., Chicago, Ill.